# Technical Report Documentation Page

**1. REPORT No.**
646142-2

**2. GOVERNMENT ACCESSION No.**

**3. RECIPIENT'S CATALOG No.**

**4. TITLE AND SUBTITLE**
Laboratory Investigation of Tetrafuorethylene (TFE) As A Bridge Bearing Material

**5. REPORT DATE**
June 1970

**6. PERFORMING ORGANIZATION**


**7. AUTHOR(S)**
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**8. PERFORMING ORGANIZATION REPORT No.**
646142-2


**9. PERFORMING ORGANIZATION NAME AND ADDRESS**
State of California
Department of Public works
Division of Highways
Materials and Research Department


**10. WORK UNIT No.**

**11. CONTRACT OR GRANT No.**

**12. SPONSORING AGENCY NAME AND ADDRESS**

**13. TYPE OF REPORT & PERIOD COVERED**

**14. SPONSORING AGENCY CODE**

**15. SUPPLEMENTARY NOTES**


**16. ABSTRACT**

This is a report of a laboratory study to determine the feasibility of using Tetrafluorethylene (TFE) as a sliding bridge bearing material. A variety of bearing assemblies and designs containing TFE sliding elements were tested for friction factor and fatigue life. A maximum friction factor of 0.11 and a minimum fatigue life of 10,000 cycles were set as desirable performance limits.

Design and material variables among the bearing assemblies tested included (1) sliding elements, (2) backing material, (3) quality of bond between the bearing assembly components, and (4) the confinement of the backing material.

A bearing assembly composed of a 0.10 inch minimum thickness layer of filled TFE bonded to a high quality preformed fabric pad and sliding against either a pad of like composition or a ground stainless steel surface consistently met the above mentioned performance limits. A high quality two component epoxy adhesive was used to bond the TFE to the fabric pad.

Based on one test series, a "Leonhardt type" rotation-translation bearing also successfully met the performance requirements.

Considering California's successful experience with neoprene elastomeric bearing pads, TFE bearing assemblies are only considered economical for use in long span structures or structures subject to unusually large horizontal movements.



**17. KEYWORDS**
Bridges/structures, bridge bearings, sliding, Tetrafluoroethylene, preformed fabric, test method, specifications


**18. No. OF PAGES:**
54

**19. DRI WEBSITE LINK**
http://www.dot.ca.gov/hq/research/researchreports/1969-1970/70-10.pdf

**20. FILE NAME**
70-10.pdf

# HIGHWAY RESEARCH REPORT

# TETRAFLUOROETHYLENE (TFE) AS A BRIDGE BEARING MATERIAL

70-10

June 1970

STATE OF CALIFORNIA

BUSINESS AND TRANSPORTATION AGENCY

DEPARTMENT OF PUBLIC WORKS

DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

RESEARCH REPORT

NO. M & R 646142-2

STATE OF CALIFORNIA—TRANSPORTATION AGENCY RONALD REAGAN, *Governor*

DEPARTMENT OF PUBLIC WORKS
**DIVISION OF HIGHWAYS**
MATERIALS AND RESEARCH DEPARTMENT
5900 FOLSOM BLVD., SACRAMENTO 95819

Report M & R No. 646142-2

June 1970

Mr. J. A. Legarra
State Highway Engineer

Dear Sir:

Submitted herewith is a research report titled:

LABORATORY INVESTIGATION

OF

TETRAFLUOROETHYLENE (TFE)

AS A

BRIDGE BEARING MATERIAL

Eric F. Nordlin
Principal Investigator

John F. Boss and Richard R. Trimble
Co-Investigators

Report Prepared By
John F. Boss

Very truly yours,

JOHN L. BEATON
Materials and Research Engineer

## ABSTRACT

REFERENCE: Nordlin, E. F., Boss, J. F., and Trimble, R. R., "Laboratory Investigation of Tetrafluorethylene (TFE) as a Bridge Bearing Material", State of California, Department of Public Works, Division of Highways, Materials and Research Department. Research Report 646142-2, June 1970.

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## ACKNOWLEDGEMENTS

During the duration of this research effort, many persons at various times, contributed their time and energy. Deserving special recognition are W. H. Ames, Supervising Materials and Research Engineer, A. P. Bezzone, Senior Bridge Engineer, J. R. Stoker, Senior Bridge Engineer, W. E. Faist, Associate Materials and Research Engineer, and M. H. Johnson, Associate Materials and Research Engineer. Also, the fine cooperation received from the Materials and Research Department Machine Shop, under the direction of R. E. Wilhelmy and H. B. Skewes, in constructing and maintaining the Bridge Bearing Assembly Fatigue Tester is greatly appreciated.

TABLE OF CONTENTS

# 1. INTRODUCTION

## A. Background and Objective

During the long history of bridge design, various methods have evolved to provide for (1) thermal length changes of bridge structures, (2) drying shrinkage of concrete bridge structures, (3) shortening during stressing of post tensioned, prestressed bridge structures, and (4) girder end-rotation at abutments and columns. Generally, these methods should comply with the following requirements:

1. Be able to support bridge loadings (dead load, live load, impact, etc.).

2. Be able to accommodate the maximum expected bridge movement with the least possible resisting force.

3. Perform satisfactorily for the expected number of cyclic reversals during the design life of the bridge.

4. Perform with minimal maintenance during the design life of the bridge.

5. Not be affected by environmental conditions during the design life of the bridge (temperature, moisture, ozone, oil, debris and other foreign materials).

6. Be economically feasible.

A previous report of work done under this bridge bearing pad project covers the development of design criteria and specifications for elastomeric bridge bearing pads[1]. These elastomeric pads are now being very successfully used on almost all short and intermediate span highway bridges designed by the California Division of Highways.

However, one design criteria for elastomeric bearing pads is that the total thickness of these pads must be at least two times the maximum expected horizontal movement. Therefore, the cost of these bearing pads varies directly with the amount of expected horizontal movement (which is dependent on span length). A sliding bridge bearing (the cost of which is independent of the expected movement) is, consequently, more economical for long span structures in many cases.

Prior to 1963, self lubricating metallic bearing pad systems were being used for long-span structures by the California Division of Highways. These sliding bearings, in addition to having a relatively high first cost, had been performing with only marginal effectiveness. The "freezing" action that occurred when relatively small particles accumulated on the sliding interface proved to be a real maintenance headache. The Division of Highways was, therefore, looking for a cheaper, more maintenance-free sliding bridge bearing assembly.

Nylon fabric and several plastic materials were suggested but laboratory testing indicated that their coefficients of friction were significantly higher than that provided by the self-lubricating metallic bearings. Virgin TFE was also tested and found to be unacceptable due to its low resistance to wear and its susceptibility to cold flow under compressive loads such as found in bridges (800-2000 psi). However, laboratory testing in the early 1960's indicated that the addition of certain fillers to the TFE would significantly reduce these problems. Consequently, bridge bearing assemblies containing reinforced (i.e., filled) TFE were installed in several bridges located in the eastern United States in the early 1960's. The first use of this type of bearing assembly by the California Division of Highways occurred in 1965.

The study reported herein was initiated in the early 1960's with the objective of determining the feasibility of using TFE as a bridge bearing pad material. Included in this report are the results of tests of several combinations of different sliding elements, backing materials, bonding materials and processes, and backing material restraint systems that have been developed in cooperation with industry. A tentative specification for TFE bearings, based on the results of much of this testing, has been developed and is documented in Appendix B.

B. Testing Program

Almost all testing was performed on bearing assemblies supplied by the various manufacturers and distributors. These were either assemblies already on the market or special prototypes submitted for preliminary testing. Late in the testing program, some bearing assemblies were fabricated in the Division of Highways laboratory to test various methods of bonding TFE to its backing. The majority of the bearing samples were tested at 1,200 psi normal load, 4½ inches/minute sliding speed, and 10,000 cycles (2 inches total travel per cycle). These testing conditions were chosen to compare the performance of TFE sliding bearing assemblies with conventional self lubricating metallic sliding bearing designs as used by the Division. Other loading conditions and testing speeds were also used in some instances.

To function effectively and reliably, a sliding bridge bearing must exhibit a low coefficient of friction throughout its design life. During the elastomeric bearing pad investigation mentioned previously, a testing machine had been developed which could subject test specimens to the bearing pressures and type of cyclic lateral movements a bearing assembly would experience in a bridge (see Appendix C for a full description of this testing machine). This testing machine was used for all coefficient of friction determinations and fatigue testing during this TFE bearing assembly investigation.

Normal testing procedure was as follows (for complete Test Method see Appendix C):

1. Samples approximately 6 inches x 9 inches in size are prepared.

2. A normal pressure of 800-1200 psi is applied (normal pressure is dependent on the backing material of the assembly).

3. Lateral movement is induced by means of a hydraulic ram. The lateral resistance to movement can be monitored at all times by use of an SR-4 strain gage load cell incorporated in the hydraulic ram.

4. Sliding is continued at a sliding speed of 4½ inches per minute until failure or 10,000 cycles are completed. Failure is considered to occur when:

    a. The friction factor exceeds 0.11 or

    b. The layer of TFE extrudes due to cold flow or

    c. Delamination occurs between bearing assembly components or

    d. The backing breaks down.

Although the test sliding speed of 4½ inches/minute is unrealistically high, this speed was used to accelerate the testing program. For this reason, the friction factor maximum of 0.11 was chosen. A coefficient of friction at 0.05-0.07 is quoted by most manufacturers.

The friction factor of 0.11 maximum as specified in the Division of Highways specification for TFE Bridge Bearings and established by the testing reported herein was determined at the forementioned sliding speed of 4½ inches per minute. The coefficient of friction is lowered as sliding speeds are reduced, thus partly explaining the disparity in coefficients reported in this document and those claimed by various manufacturers. The coefficient of friction also varies, but inversely, with unit load. Static and dynamic coefficients are also different. Therefore, any design or materials specifications should define the testing parameters in establishing the coefficient of friction.

## CONCLUSIONS

The testing performed under this program was by no means an exhaustive study of all of the possible TFE sliding bearing assemblies. It was encouraging to note, however, that several combinations of TFE bearing components did meet the desirable levels of friction factor (0.11 maximum) and fatigue life (10,000 cycles minimum). In-service experience and the results of this testing indicate that with careful design and assembly, TFE sliding bearing assemblies are satisfactory for use in bridges. However, considering California's successful experience with neoprene elastomeric bearing pads and the current cost of TFE assemblies, economic considerations may limit the use of TFE bearing pads to long span structures or structures subject to unusually large horizontal movements.

Current California TFE sliding bearing assemblies Design and Material Standards are based on the results of this test program and are as follows:

A TFE friction surface backed with a preformed fabric pad is a satisfactory expansion bridge bearing provided the following conditions exist:

1. The friction interface must be TFE vs. TFE or TFE vs. Surface Ground Stainless Steel (32 RMS finish or better and 16% minimum chrome content).

2. A high quality sintered virgin TFE material, reinforced with a suitable filler, must be used. The layer of TFE should be at least 0.10 inches thick, unless laminated to steel, to prevent failures from combined stresses.

3. The preformed fabric pad backing must conform to Federal Specification MIL-C-882.

4. The adhesive used for bonding the TFE to the fabric backing must be high quality two-component epoxy which is properly mixed and applied.

5. The top sliding member must be large enough to be in contact with 100% of the bottom member during the entire lateral movement cycle. This will minimize the "plowing" effects adverse to bearing movements and will also minimize the possibility of debris accumulating on the sliding interface.

6. Provisions must be made to keep concrete grout and other foreign materials from the plane between the slip surfaces during construction of the bridge structure.

On the basis of one test series, the "Leonhardt type" rotation-translation bearing is a promising design concept for use in long span bridge structures where relatively large magnitudes of joint rotation and translation are anticipated.

## 3. DISCUSSION

### A. Test Criteria

This phase of the bridge bearing assembly testing program was initiated to evaluate the various TFE sliding bridge bearings on the market for possible use in California state highway bridges. At the time this study began (1963), the development and testing of elastomeric bridge bearing pads by the California Division of Highways had been underway for some time, and the design and economic features of these bearings were emerging as very favorable (as later reported in Ref. 1). Thus, very early in this TFE bridge bearing study, it was decided that the objective was not to replace the elastomeric bearing pads now so successfully used on short and medium span structures, but rather to provide a more efficient bearing for long span bridges.

The two basic criteria that the TFE bridge bearing assemblies were tested for were (1) a low lateral resistance to sliding and (2) a maintenance-free service life with little increase in sliding resistance during this service life. During the testing program reported herein, it was found that the following factors greatly influenced the degree to which the TFE expansion bearings satisfied these criteria:

1. Composition of the sliding elements.

2. Composition of backing materials.

3. Bond between the various components of the bearing assemblies.

4. Geometry of the assemblies.

5. Degree of confinement of the backing material.

### B. Composition of the Sliding Elements

The sliding surfaces of several of the first TFE bearing assemblies tested were thin layers of unreinforced pure virgin TFE. In all these tests the TFE either extruded along the perimeter of the pad (Figure 1) or tore and pulled loose from its backing (Figure 2). After several hundred cycles of testing of these assemblies, there was a gradual increase of friction to undesirable levels (above 0.11). These conditions were caused by the susceptibility of unreinforced TFE to cold flow at bearing pressures of 500 psi and above.

To combat this undesirable effect, bridge bearing manufacturers began using TFE reinforced with inert fillers. Glass fibers or asbestos fibers in quantities ranging from 15 to 25% by volume have been the most successful fillers. Filler quantities below 15% do not provide adequate reinforcing while quantities higher than 25% tend to raise the friction values to undesirable levels (above 0.11). A graphite filled TFE also performed adequately; however, the manufacturer did not volunteer the amount of graphite present. As can be seen in Appendix A, all the bearing assemblies that were tested successfully contained TFE reinforced with one of these three materials.

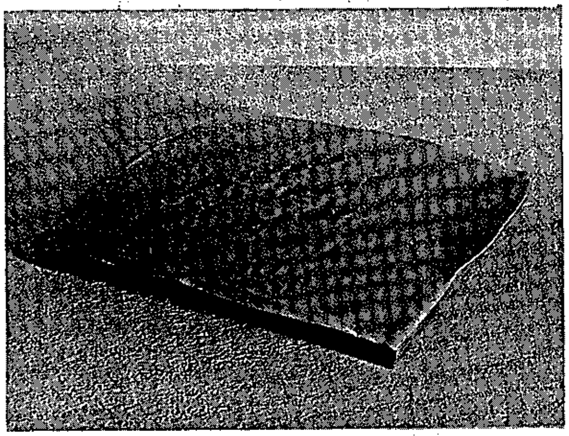


FIGURE 1

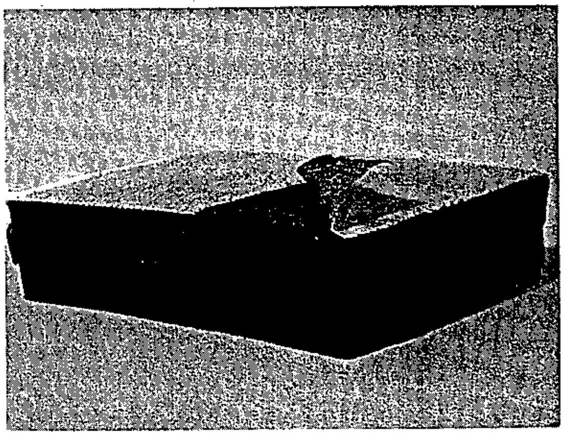


FIGURE 2

Samples with bronze filled TFE, and several samples with unidentified fillers, exhibited friction values above 0.11, leading to eventual deterioration of the bearing assembly.

Two types of pad assemblies using TFE impregnated fabric as the sliding surfaces were tested. One type possessed such a high friction factor that sliding could not be induced (coefficient of friction over 0.20). The preformed backing of these samples deformed excessively due to the extreme shear forces and testing was discontinued. The other type failed due to extreme plastic deformation of the sliding interface and subsequent complete backing deterioration.

For bridge bearings composed of TFE bonded to preformed fabric pads, it was found from our testing that the layers of TFE should be at least 0.10 inch thick. Pads with thinner TFE layers failed due to TFE creep and other combined stresses. However, the same type of TFE, bonded to a 1/8 inch or thicker steel plate, performed adequately in thickness as low as 1/32 inch.

Initially it was thought that the lowest coefficient of friction could be obtained with TFE sliding against TFE. Later, several other friction interfaces were tested. TFE sliding against a ground stainless steel surface (32 RMS finish or better) performed slightly better, on the average, than TFE vs. TFE. Other sliding interfaces that were tried were TFE vs. (1) galvanized steel,

(2) cold rolled steel, (3) aluminum, and (4) cold rolled steel sprayed with TFE. These all resulted in inadequate performance with friction factors over 0.11 (see Table 1 below). A few tests of asbestos fiber reinforced TFE sliding against galvanized steel resulted in average coefficients of friction of 0.10 but wear was about 20% in 10,000 cycles.

TABLE 1

Friction Values

TFE vs. Various Surfaces

| Surface | Average Coef. of Friction |
|---|---|
| TFE | .09 |
| Ground stainless steel | .08 |
| Galvanized steel (vs. glass fiber filled TFE) | .13 |
| Unground cold-rolled steel | .15 |
| Aluminum | .12 |
| Cold rolled steel sprayed with TFE | .12 |

C. Composition of Backing Materials

Three types of backing material were tested: (1) TFE bonded to steel, (2) TFE bonded to preformed fabric pads, and (3) TFE bonded to a neoprene elastomeric backing. (For the purpose of this discussion, the upper and lower bearing assemblies were of identical construction, although various combinations were also tested.)

Several TFE-on-steel bearing assemblies were tested under this test program, even though they were too rigid to be suitable for bridge bearings. Any girder end rotation at all would create very high localized loading conditions. However, bearing assemblies of this type exhibited good friction and fatigue characteristics. They are by far the easiest to manufacture while maintaining good quality control and would seem to be well suited for buildings, pipe lines, and other applications where end rotation is nonexistent. Mechanically rotating

TFE-steel bridge bearings (see Figure 3) have been suggested, but none were ever submitted for testing.

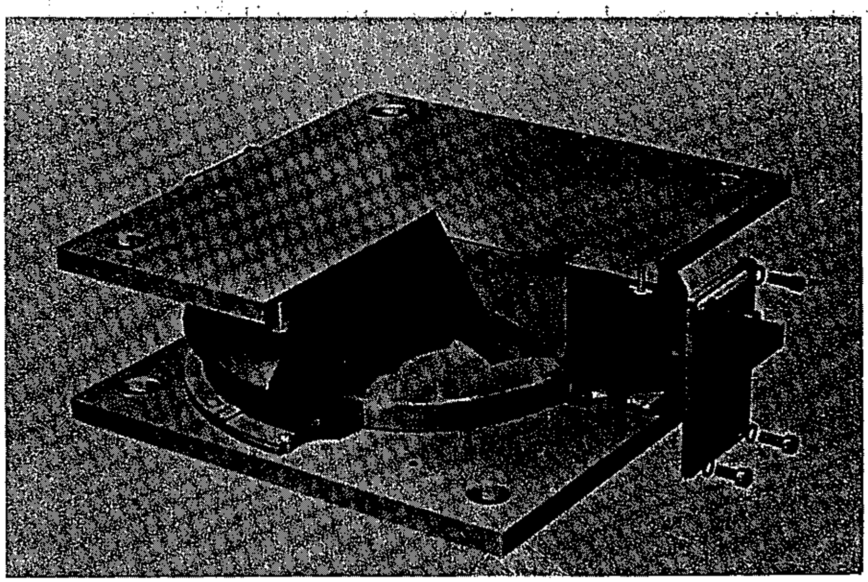


FIGURE 3

The need for TFE sliding bearing assemblies to accommodate girder end rotation led to the development of flexible and semi-flexible backings. A flexible backing is designed to accommodate any expected amount of rotation up to 2°, whereas a semi-flexible backing is used primarily for even load distribution with only a limited amount of rotational capability (0.5° maximum).

A multitude of combinations of TFE with neoprene and other elastomers with and without steel reinforcing laminates were submitted for testing as flexible backed pads. This type of backing will act as an elastomeric bearing pad until the internal shear resistance of the neoprene exceeds the static coefficient of friction of the TFE. Present California specifications for neoprene bearing pads limit the lateral deflection of the pad to 1/2 its thickness. In previous unpublished testing by the California Division of Highways, it had been determined that for Shore A 55 durometer hardness neoprene, a lateral force equal to 0.06-0.08 times the normal load is required to laterally deflect the pad 1/2 its thickness. Since most TFE sliding bearings exhibited higher friction values (0.08-0.10), it was felt that a harder neoprene should generally be used. The first test samples submitted with a neoprene backing were made with 50-60 durometer neoprene. As was expected, the lateral movement of the neoprene backing was much more than 1/2 the neoprene thickness before sliding occurred at the TFE interface. Gradual deterioration and delamination of the pad occurred during testing with a complete failure much before the 10,000 cycles were reached.

Other factors affecting the efficiency and fatigue life of neoprene backed pads were:

1. The TFE, when bonded directly to the neoprene, would deform excessively, leading to ultimate bond breakdown between the two layers (Figure 4).

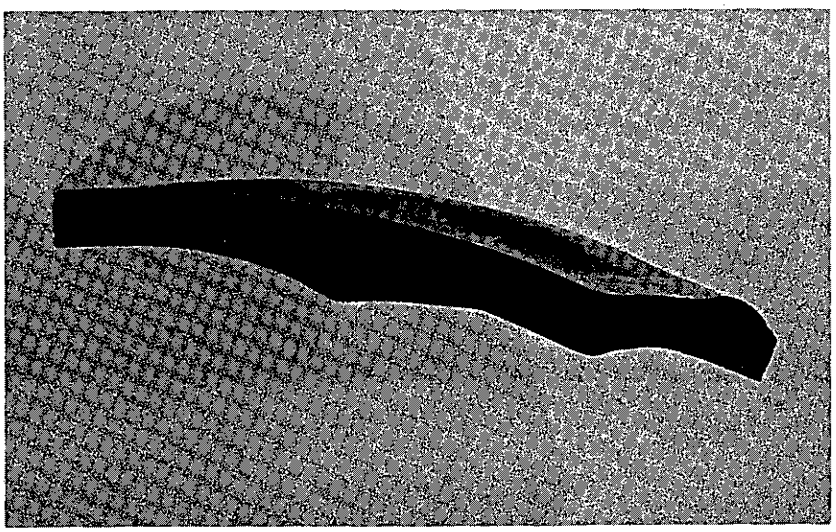


FIGURE 4

2. Thin steel sheets placed between the neoprene and TFE would deform under load, leading to either delamination between the neoprene and steel or excessive deformation of the TFE. Testing indicated that steel reinforcing sheet laminates should be 10 gage or thicker.

3. Many of the neoprene backed TFE bearing assemblies experienced bond failure between the neoprene and the steel sheet. Bond stresses are extremely high due to the nonuniform distribution of shear stresses to the bonding agent. (Any bonding of steel to neoprene should be accomplished by vulcanizing.)

4. Compressive load was limited to 800 psi (maximum allowable for neoprene elastomeric bearings) which resulted in higher

friction values than those with TFE preformed pad assemblies which were tested at 1200 psi. For TFE, friction values vary inversely with normal load.

Toward the end of the testing program, one neoprene backed TFE sliding bearing assembly completed 10,000 cycles successfully (Figure 5). This bearing consisted of 1/16 inch glass filled (15%) TFE layer bonded to a 1/8 inch steel sheet which was in turn bonded to a 1/2 inch thick 65 durometer neoprene pad. The opposing assembly consisted of a 1/16 inch TFE layer bonded to a 1/8 inch steel backing plate. Friction values ranged from 0.07 to 0.10, and maximum lateral deflection of the neoprene was 3/8 inch. The compressive load on this bearing was also 800 psi. If future design requirements indicate a need for this type of bearing, design and material standards for neoprene backed TFE sliding bearings will be developed through additional research. Presently, the very limited laboratory success with this type of TFE sliding bearing does not appear to warrant this action.

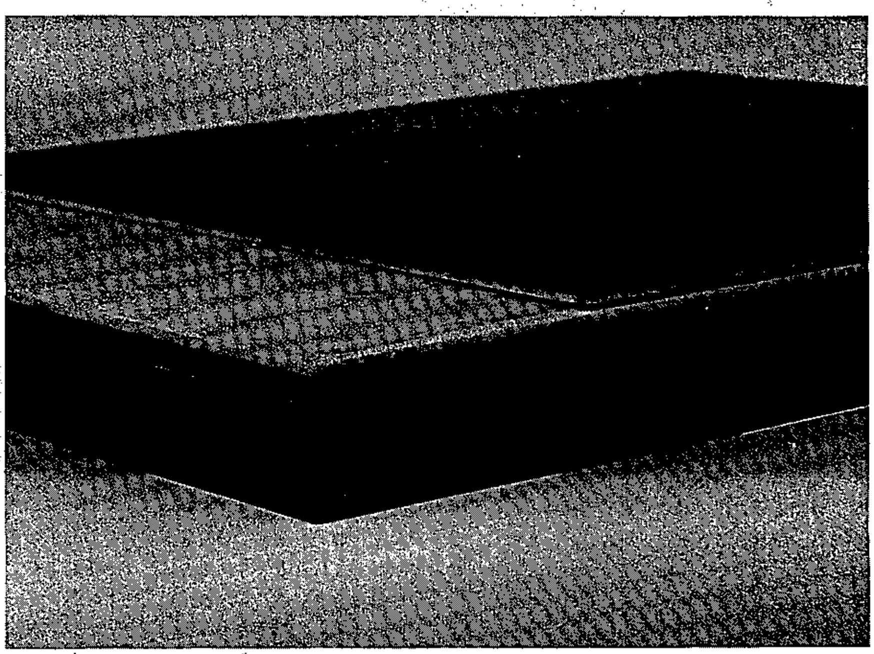


FIGURE 5

The most successful TFE sliding bearing assemblies tested were those backed with good quality preformed fabric pads. These pads are comprised of multiple plies of lightweight cotton duck, completely impregnated with elastomers containing anti-oxidants and mildew inhibitors. These plies are stacked to the desired thickness, prestressed, and then vulcanized and cured under pressure (see Appendix D).

Only those TFE bearing assemblies constructed with preformed fabric pads meeting Federal Specification MIL-C-882 consistently met the standards for friction and fatigue (see Appendix A). Of course, the other requirements for TFE and bond, as outlined in other sections of this report, must also be met. Backing pad thicknesses of both 1/2 inch and 1 inch worked adequately, although some binder extrusion and backing deformation were evident in the 1 inch fabric pad after about 6,000 cycles.

The TFE bearing assemblies backed with preformed fabric pads not meeting Federal Specification MIL-C-882 usually failed at the TFE-preformed fabric interface before completing 10,000 cycles in the bearing assembly fatigue testing machine. Either the first few layers of the fabric would rupture, progressively leading to complete bearing assembly failure, or delamination would occur due to the excessive stresses occurring at the bond line (see Figures 6 through 8).

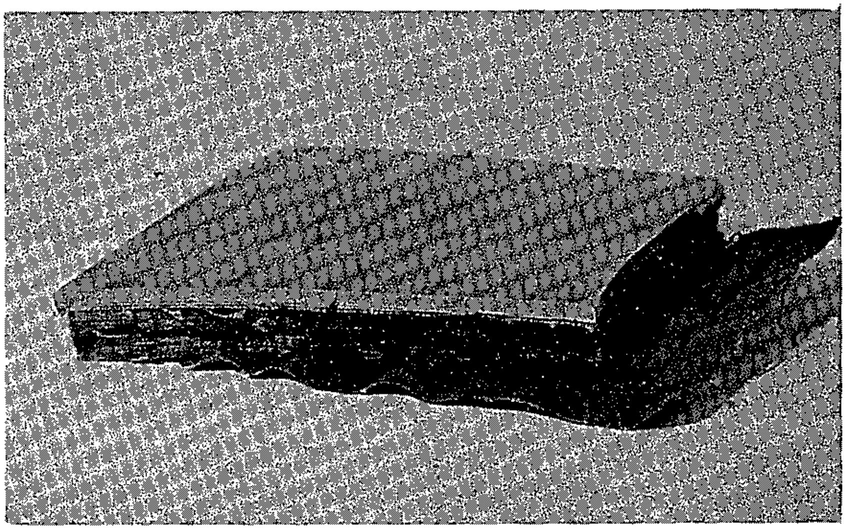
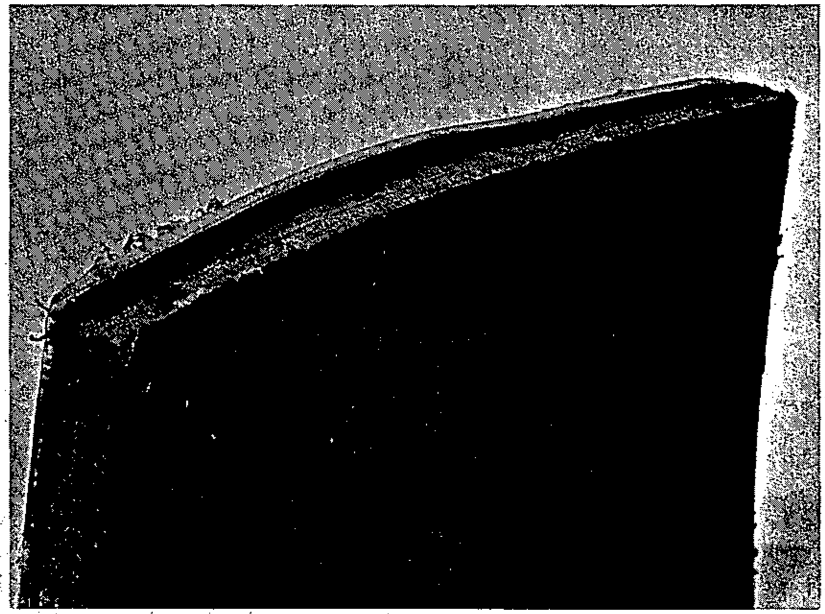


FIGURE 6

General deterioration of preformed fabric pad and delamination of exterior layer.



Delamination of preformed fabric pad
in upper layers and creep of TFE.

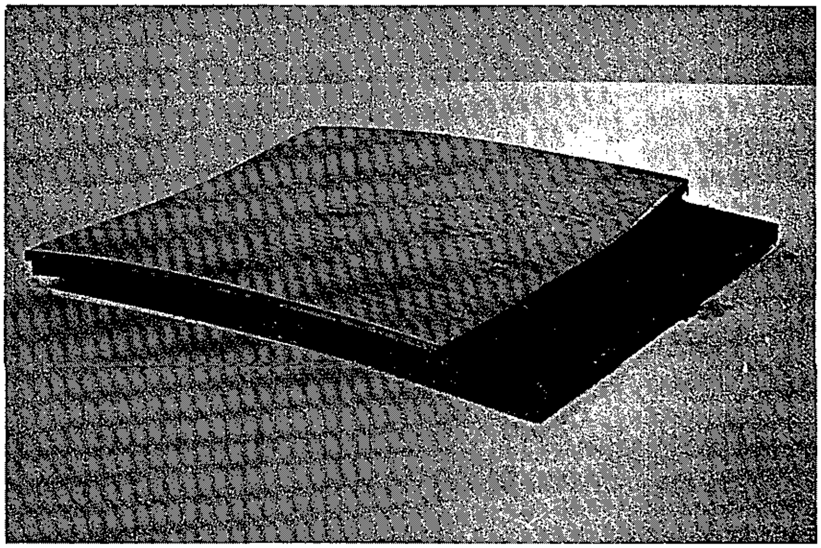


FIGURE 8

Ply separation of preformed fabric
pad along pad centerline.

D. Testing of a "Rotation-Translation" TFE Bridge Bearing

During the latter part of 1969, a "Rotation-Translation" TFE bridge bearing incorporating the design concept of Prof. Fritz Leonhardt[6] was submitted to the department for testing (see Figures 9, 10, and 11). This bearing is designed to accommodate 2000+ psi compressive load and 1-2° girder end rotation. Horizontal movement is accommodated at the TFE vs. stainless steel interface while the confined neoprene permits rotation of the sliding surface at compressive unit loads of over 2000 psi. This unit load is well within the working range of thin layers of TFE bonded to steel. The TFE at the sliding interface was unfilled virgin tetrafluoroethylene 3/32 inch thick and was recessed into the steel backing plate by 1/16 inch.

This bearing was tested for its friction factor and fatigue life according to the previously mentioned test procedure with the following modifications:

1. Compressive load was increased to 2000 psi.

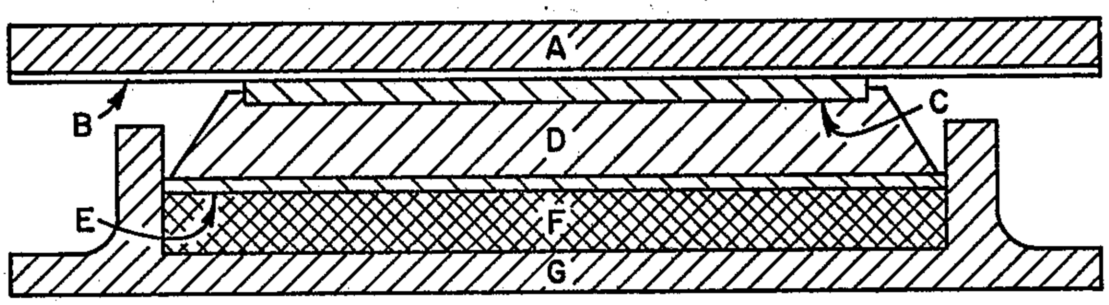
2. For several intervals, the coefficient of friction readings were taken at very slow sliding speeds.

The bearing performed very well through 10,000 2-inch cycles with coefficient of friction readings averaging 0.07 at sliding speeds of 4.5 inches/minute, and 0.04 at speeds of 0.01 inches/minute. (This decrease in coefficient of friction with decreased sliding speeds is typical for TFE bearings.) Close examination of the bearing after completion of this test showed very little TFE cold flow or surface wear.

Next, the bridge bearing fatigue testing machine was readjusted to produce both sliding and end rotation (1.5° maximum) during each cycle. The bearing was again subjected to 10,000 cycles (5000 cycles @ 0° to -1.5° and 5000 cycles @ 0° to +1.5°). The bearing performed extremely well, with no damage to the neoprene layer and no increase in friction from that measured during the first phase of this test. There was no significant wear of the TFE after 20,000 cycles of testing although some flaking was evident.

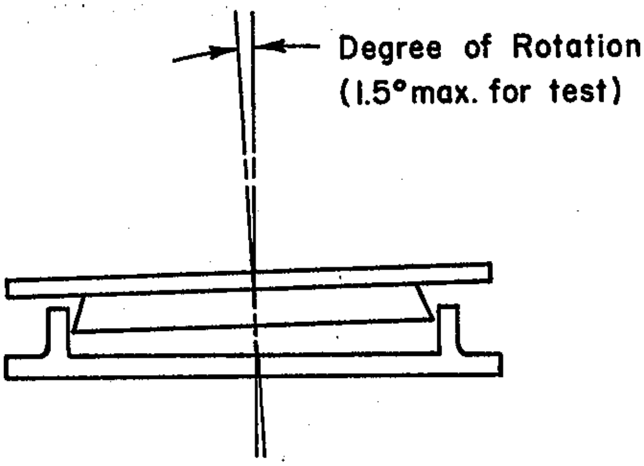
A glass filled TFE bearing of this type was tested at a constant compressive load of 2000 psi and subjected to 10,000 2-inch cycles at sliding speeds of 4.5 inches/minute. This bearing was tested through 3500 cycles with no end rotation followed by 6500 cycles of end rotation from -1.5° to +1.5°. The bearing showed good performance throughout the test with an average coefficient of friction of 0.06.

These test results indicate that this Leonhardt type bearing is an acceptable design for use under long span structures with (1) high unit loads at the supports, (2) large horizontal movements, and (3) one to two degrees of girder end rotation.




NOTES: A-Steel Sole Plate
B-Stainless Steel Sliding Face - 32 RMS finish.
C-Virgin TFE - 3/32" thick
D-Steel Backing Plate
E-Fiberglass Filled TFE Washer - 1/16" thick
F-Neoprene - 55 Durometer Hardness - 1/2" thick
G-Steel Housing

CROSS SECTION OF 6" DIA. BEARING




ROTATION

Figure 9

DIAGRAM OF LEONHARDT TYPE ROTATION-TRANSLATION TFE BRIDGE BEARING

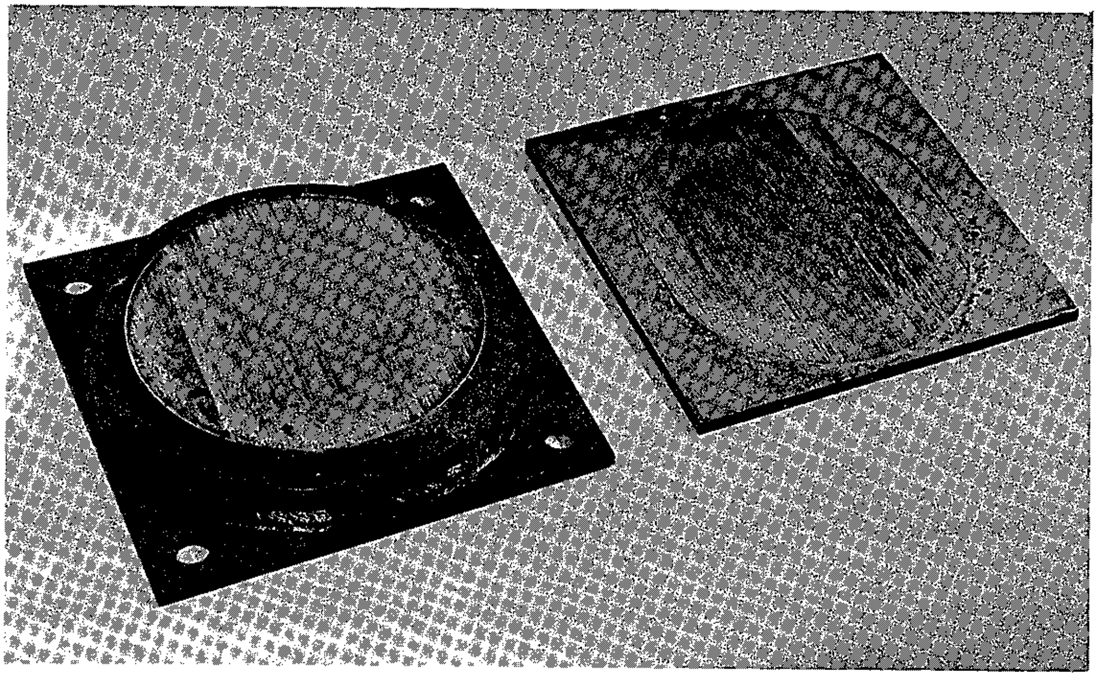


FIGURE 10

Leonhardt type bearing after completion of 20,000 cycles of testing. Note worn particles of TFE along bearing periphery.

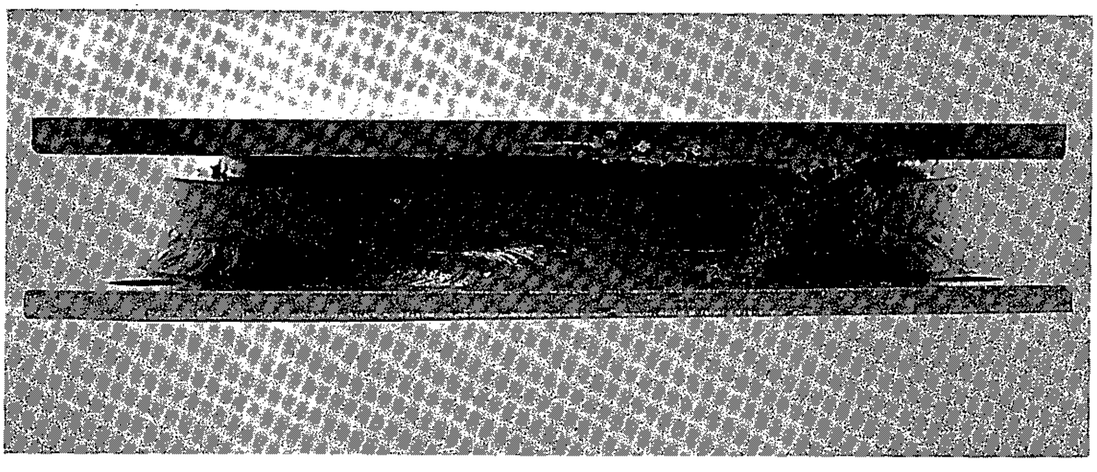


FIGURE 11

Leonhardt type bearing after completion of 20,000 cycles of testing. Note worn particles of TFE along bearing periphery.

## E. Other Factors

During the testing program, several other factors affecting the performance of the TFE sliding bridge bearings became apparent. One indication of this was the variation of friction values during one complete translatory cycle (see Figure 12). Part of this variation is due to the "bow wave" phenomenon as illustrated diagrammatically in Figures 13a and 13b. As shown in Figure 13a, when top and bottom pads are of the same size, two "bow waves" are formed. This plowing effect can increase the friction value by as much as 0.02. By making one pad larger than the other, as in Figure 13b, only one bow wave is formed, thereby reducing the maximum coefficient of friction. The above phenomenon is accentuated with bearings using unreinforced, flexible or semi-flexible backing material for both upper and lower bearing assemblies.

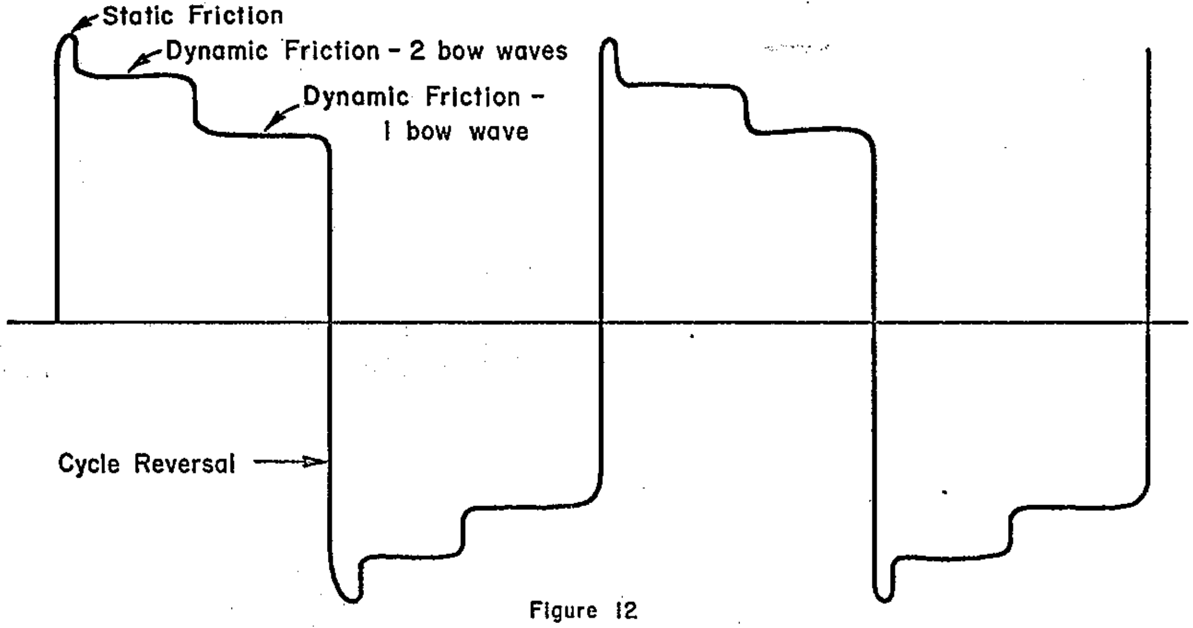
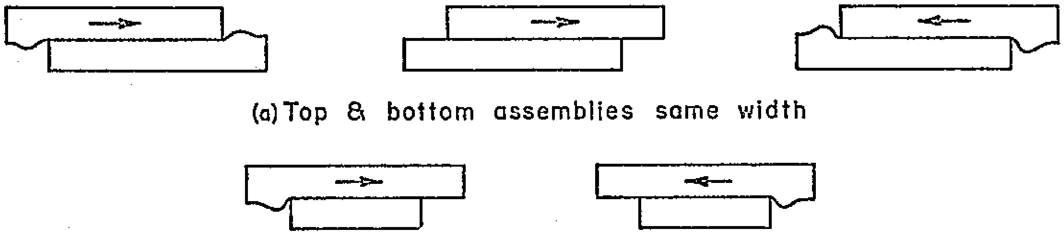



Figure 12

VARIATION IN FRICTION DURING TESTING CYCLES



(a) Top & bottom assemblies same width

(b) Top assembly wider than bottom assembly

Figure 13

BOW WAVE EFFECT (exaggerated scale)

Another variation in friction factor is caused by dissimilar values in static and dynamic friction factors, as is shown at the beginning of each cycle reversal in Figure 12. Contrary to most published reports, the static coefficient of friction for all TFE bearing assemblies tested was higher than the dynamic coefficient of friction. For most TFE bearings meeting the prescribed design criteria, static friction averaged approximately 0.02 higher than dynamic friction. This variation seemed to be independent of testing speed or normal pressure.

On several occasions, initial "breakfree" sliding was very difficult to obtain on new bearing assemblies. This movement either came at a very high lateral resistance or not at all. However, once sliding was induced and several cycles had been completed, friction values would drop to normal. The reason for this behavior is that during the skiving operation of forming TFE sheets from solid cylinders, the skiving knife cuts across reinforcing fibers (glass, asbestos, etc.). These fibers create a very rough surface until sliding has taken place. During sliding the cut ends of the fibers will be coated with TFE, dropping friction drastically. For all TFE bearing assemblies, therefore, the TFE surface should be burnished before installation.

One other factor that affected the performance of TFE assemblies to a great degree was the type and quality of bond between the sliding surface and its backing. Two basic types of bonding agents were tested: contact-type rubber cement and two-component epoxies. The contact cement failed rather early (in the range of 2000 to 3000 cycles) in the fatigue tests, thereby ruling out this system as a dependable bonding agent. The epoxy adhesive system performed very well in most cases, with occasional failures attributed to poor application practices.

After some laboratory experimentation, it was found that epoxy mixes which were thought to be identical would perform satisfactorily in one case and fail in another. This phenomena occurred even though the shearing forces (friction factors) were of approximately the same magnitude. An investigation of the epoxy application procedures that had been used for the bearing assemblies that experienced bond failures uncovered several serious shortcomings. An extreme amount of voids was present at the bond line in many cases (up to 75% of the contact area). For others, either the TFE had not been etched properly or the backing had not been thoroughly cleaned. It was found that to assure a successful, lasting bond, rigorous cleaning of the backing material with acetone as well as etching of the TFE surface to be bonded must be performed. In addition, the epoxy application must be uniform in thickness with a complete coverage free from voids, with a minimum film thickness combined with pressure bonding to insure these conditions. The need for pressure bonding cannot be over emphasized as only those pads fabricated in this manner were successful in meeting the established performance standards. The extreme care required in obtaining adequate bonding confines this to a shop rather than a field operation.

It was found that the bond quality affects the coefficient of friction as well as the durability of the pad. A bond which contains an excessive amount of voids, or an excessive amount of bonding material, tends to produce a rippled pad surface (see Figure 1). This irregular sliding surface obviously increases the coefficient of friction.

F. Field Observations

During the early stages of this test program, it became evident that the TFE bridge bearing assemblies on the market at that time could not economically compete with elastomeric bridge bearing pads except on very long structures. Therefore, the use of TFE sliding bridge assemblies on California Division of Highways bridges has been limited to a total of 17 structures to date. Some of these were field test installations while the others had unusual conditions such as large expected movements where TFE bearings were the most desirable alternative (see Figures 14, 15, and 16).

FIGURE 14

The above picture shows a TFE-preformed fabric pad assembly in place on top of a bridge abutment prior to casting a prestressed concrete box girder.

FIGURE 15

The above picture shows an elevation view looking in toward the abutment after casting the concrete box girder referred to in Fig. 14. Note the TFE-preformed fabric pad assembly on top of the bridge abutment.

All of the TFE bearing assemblies that have been installed to date consist of filled TFE sliding surfaces bonded directly to preformed fabric pads. Both top and bottom sliding components are of this type. Of all the combinations tested in the laboratory, this design resulted in the most consistent test performance (Figure 17 shows this type, after 10,000 cycles of testing.) To date there have been no reported failures or problems of these bearing assemblies.

The success of this TFE sliding bridge bearing design led to the development of the design and material specifications attached in Appendix B. The accompanying Test Method No. Calif. 663 (Appendix C) was formulated from the experience gained in both the elastomeric and TFE bearing phases of this project and applies to the testing of both.

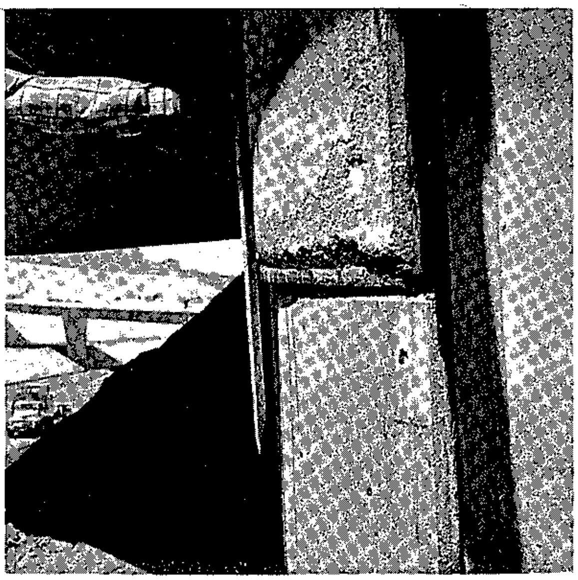


FIGURE 16

The above picture shows the elastic shortening of the cast-in-place prestressed concrete box girder bridge shown in Figures 14 and 15 immediately after prestressing. This movement was effectively accommodated by the TFE-preformed fabric pad bearing assembly.

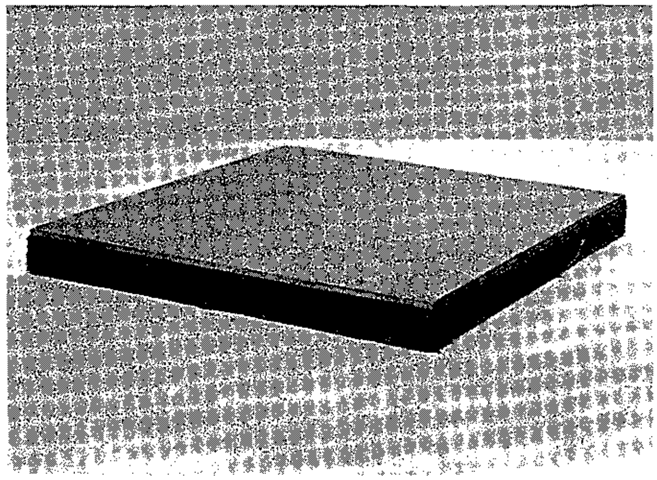


FIGURE 17

The above picture shows a TFE bearing pad bonded to a preformed fabric pad after 10,000 cycles of laboratory testing.

... resulted in the most con... was
... shows this type, ... 10,000 cf les
... here however no reported failures
... bearing assemblies.

... sliding surface bearing design featured
... the design and material specifications
... is 8. The Recommended ...

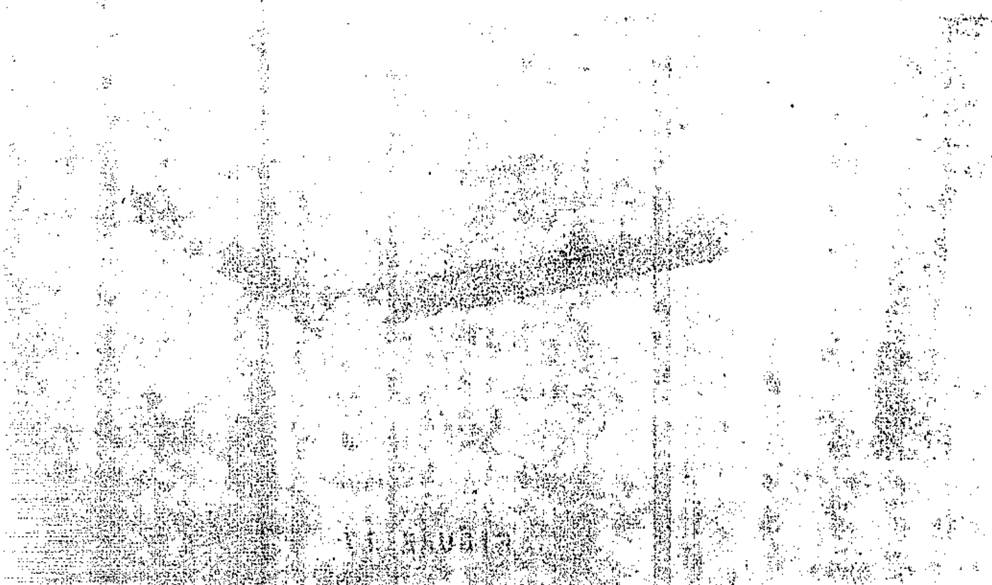
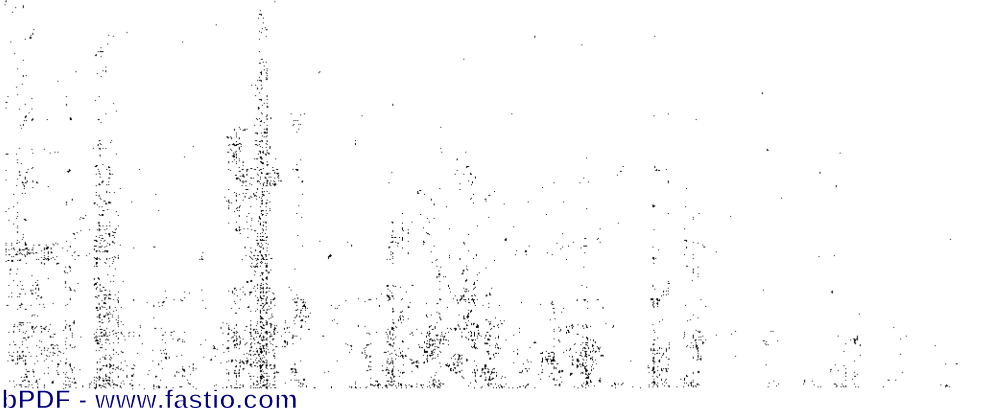


FIGURE 11

... shows ... The above picture shows



## REFERENCES


1. Nordlin, E. F., J. R. Stoker, and R. R. Trimble, "Laboratory and Field Performance of Elastomeric Bridge Bearing Pads", M & R 646142-1, California Department of Public Works, Division of Highways, Sacramento, January 1968.

2. Taylor, M. E., "Low Friction Sliding Surfaces for Bridge Bearings: PTFE Weave", Road Research Laboratory, Ministry of Transport, 1967.

3. Long, J. E., "The Performance of PTFE in Bridge Bearings", Civil Engineering and Public Works Review, May 1969.

4. "Fluorocarbon Plastics", Materials in Design Engineering, February 1964.

5. E. I. DuPont de Nemours & Co. (Inc.), "Technical Information Manual - Bearing Pads of Teflon".

6. Leonhardt, Fritz and Andra, Wolfhart, "New Developments Concerning Bearings for Use in Building; Rubber Pad and Cup Bearings", Special Publication from "Die Bautechnik", 39th year (1962), No. 2, pp 37-50.

# APPENDIX A

# AVERAGE FRICTION VALUES AND FATIGUE LIFE FOR VARIOUS TFE BEARING ASSEMBLIES

## I. Bearing Assemblies Tested For 10,000 Cycles With No Deterioration

| TFE* Type | Backing* Type | Sliding Interface* | Normal Pressure psi | Average Coef. of Friction | No. of Assy. Tests |
|---|---|---|---|---|---|
| 1 | a | A | 1200 | 0.09 | 12 |
| 2 | a | A | 1200 | 0.09 | 1 |
| 3 | a | A | 1200 | 0.08 | 2 |
| 1 | a | A | 800 | 0.11 | 2 |
| 3 | a | A | 800 | 0.10 | 1 |
| 1 | a | B | 1200 | 0.08 | 7 |
| 2 | a | B | 1200 | 0.08 | 2 |
| 1 | b | A | 1200 | 0.08 | 3 |
| 1 | b | A | 1000 | 0.09 | 2 |
| 1 | b | A | 800 | 0.10 | 1 |
| 6 | b | A | 800 | 0.10 | 1 |
| 1 | a | C | 1200 | 0.11 | 4 |
| 6 | a | A | 1200 | 0.10 | 2 |
| 1 | c | B | 800 | 0.09 | 3 |
| 3 | b | A | 800 | 0.11 | 1 |

## II. Bearing Assemblies That Failed Between 5,000 and 10,000 Cycles.

| TFE* Type | Backing* Type | Sliding Interface* | Normal Pressure psi | Average Coef. of Friction | No. of Assy. Tests |
|---|---|---|---|---|---|
| 1 | c | A | 800 | 0.11 | 1 |
| 1 | a | E | 1200 | 0.13 | 3 |
| 2 | b | E | 1200 | 0.11 | 2 |
| 2 | a | D | 1200 | 0.12 | 1 |
| 5 | f | A | 1200 | 0.06 | 2 |
| 1 | e | A | 1200 | 0.12 | 4 |
| 1 | e | A | 800 | 0.12 | 3 |
| 4 | e | A | 1200 | 0.11 | 2 |

## III. Bearing Assemblies That Failed Between Zero and 5,000 Cycles.

| TFE* Type | Backing* Type | Sliding Interface* | Normal Pressure psi | Average Coef. of Friction | No. of Assy. Tests |
|---|---|---|---|---|---|
| 1** | a | A | 1200 | 0.09 | 1 |
| 1** | e | A | 1200 | 0.11 | 1 |
| 2 | e | A | 1200 | 0.10 | 1 |
| 5 | e | B | 1200 | 0.15 | 1 |
| 7 | e | A | 1200 | 0.08 | 1 |
| 7 | e | A | 800 | 0.09 | 1 |
| 1 | a | D | 1200 | 0.15 | 1 |
| 1 | a | F | 1200 | 0.12 | 1 |
| 3 | d | A | 800 | 0.13 | 2 |
| 3 | c | A | 800 | 0.16 | 1 |
| 3 | c | G | 1200 | 0.12 | 1 |
| 4 | c | B | 1200 | 0.17 | 1 |
| 7 | g | B | 1100 | 0.08 | 3 |

IV. Bearing Assemblies With No Sliding At Interface.

| TFE* Type | Backing* Type | Sliding Interface* | Normal Pressure psi | Average Coef. of Friction | No. of Assy. Tests |
|---|---|---|---|---|---|
| 1 | d | A | 800 | - | 2 |
| 1 | d | B | 800 | - | 2 |
| 2 | d | B | 800 | - | 1 |
| 3 | d | B | 800 | - | 1 |
| 1 | d | G | 1200 | - | 1 |
| 6 | a | G | 1200 | - | 2 |
| 5 | f | B | 1200 | - | 1 |
| 5 | e | B | 1200 | - | 2 |

* TFE Types

1- Glass filled
2- Asbestos filled
3- Carbon filled
4- Bronze filled
5- TFE impregnated fabric
6- Unknown
7- Unreinforced

Backing Type

a- Preformed fabric meeting Federal Spec.
b- Steel
c- Neoprene (Shore A Durometer ≥ 65)
d- Neoprene (Shore A Durometer ≤ 60)
e- Preformed fabric not meeting Federal specifications
f- Corfam
g- Polyurethane

Sliding Interface

A- TFE vs. Pad of like composition
B- TFE vs. Ground stainless steel (32 RMS finish)
C- TFE vs. TFE sprayed steel
D- TFE vs. Unground cold rolled steel
E- TFE vs. Galvanized steel
F- TFE vs. Aluminum
G- TFE vs. TFE bonded to steel backing

** TFE bonded to backing with rubber cement. For all other assemblies, TFE bonded to backing with a two component epoxy.

# TENTATIVE SPECIFICATION FOR TFE BRIDGE BEARING PADS

The bearing pads at                                      shall be furnished and installed in accordance with the details shown on the plans and the requirements in these special provisions.

The bearing pads shall consist of a thickness of 0.1 ± 0.01 inch of filled virgin tetrafluoroethylene (TFE) fluorocarbon resin sheet bonded with a compatible, 2 component, medium viscosity epoxy resin to a 0.5 ± 0.05 inch thickness of preformed fabric pad conforming to Federal Specification MIL-C-882.

All bonding shall be carefully performed in a shop operation subject to the approval of the Engineer. The adhesive shall be applied without voids around the perimeter edges of the preformed fabric pad, and the remaining contact area to be bonded shall have a maximum of 15% voids in the adhesive coating within any one square foot of area. Allowable voids shall be well dispersed within this area. Bonding operations shall be available for State inspection. After completion of the bonding operation, the sliding surface of the TFE sheet shall be polished smooth.

A certificate of compliance will be required certifying that a high quality sintered virgin TFE fluorocarbon resin is utilized in the bearing pad and that the preformed fabric pad meets Federal Specification MIL-C-882.

The TFE fluorocarbon resin sheet shall be reinforced with a suitable filler such as glass fiber, asbestos fiber, graphite or like reinforcing material that will minimize the cold creep tendencies of the fluorocarbon resin.

Acceptance of the expansion bearing pads will be based on the following tests conducted in accordance with Test Method No. Calif. 663 by the Materials and Research Department on a full size pad from the production run:

> The pads shall withstand a minimum of 10,000 2-inch cycles at a constant normal loading of 1200 pounds per square inch with a maximum coefficient of friction of 0.11 and an average of 0.09 throughout the test. The test specimens shall exhibit no indication of excessive creep, delamination or other signs of distress after completing the 10,000 cycles in the Materials and Research Department expansion bearing fatigue machine. The testing speed will not exceed 4½ inches per minute.

TFE fluorocarbon resin bearing pads will be paid for at the contract price per square foot.

The contract price paid per square foot for the TFE fluorocarbon resin bearing pads shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals, and for doing all work involved in furnishing and placing the bearing pads, complete in place, as shown on the plans and as specified herein.

State of California
Department of Public Works
Division of Highways

MATERIALS AND RESEARCH DEPARTMENT

Test Method No. Calif. 663-A
October 2, 1967
(6 pages)

# TESTING OF BRIDGE EXPANSION BEARING PADS FOR COEFFICIENT OF FRICTION AND FATIGUE LIFE

## Scope

This test method describes the procedures to be used for the determination of the fatigue life and coefficient of friction or internal shear resistance of various bearing pad assemblies such as bronze, elastomeric, TFE (Teflon), etc.

## Procedure

### A. Testing Apparatus and Accessories

1. Expansion bearing pad fatigue testing machine. (See photograph and schematic drawing, Figures I and II.)
2. Acetone
3. Stop watch
4. SR-4 strain indicator
5. 6-inch steel scale graduated in 1/100 of an inch.

### B. Test Record Form

Use work card, Form HMR T-6028, for recording test data.

### C. Specimen Preparation

1. Clean all test specimens and both platens so that they are free of any foreign substances such as dust, grit, moisture, etc., except for the lubricants used in conjunction with the bronze specimens such as oil, grease, etc. Cut the elastomeric specimens to size (standard size 6″x 6″) and wipe clean. File smooth any rough edges on the bronze specimens and wipe clean. Use acetone to clean the bearing surfaces of TFE (Teflon) bonded specimens only.

### D. Test Procedure

1. After the specimen has been centered on the lower platen of the fatigue machine, screw the eight platen leveling rollers far enough into the platen so that they do not contact the vertical guide plates.
2. Zero in the strain indicator.
3. Apply vertical load by operating valves #1 and #2.
4. Then adjust valve #6 to maintain the required pressure as read on gage #2.
5. At this time the loading platens should be parallel; check with steel scale. If loading heads are not parallel, unload and repeat the loading procedure.
6. Remove the "at rest" shims and screw the eight platen leveling rollers finger tight against the guide plates to maintain platen stability.
7. Operate the top loading platen using the following procedure:

   a. Start hydraulic pump (start button).

   b. Open valve #5 all the way and then adjust valve #4 to maintain the proper testing speed. Note: Valve #5 must be opened before speed can be adjusted by valve #4.

   c. Adjust the testing speed by the use of a stop watch.

   d. Measure the horizontal load by use of the SR-4 strain indicator.

   e. The pressure indicated on gage #3 is controlled by valve #7. The function of valve #7 is to control the pressure applied to the horizontal ram.
8. At the end of the test period, stop and unload the machine by reversing the loading steps.

### E. Horizontal Force Measurements

During the course of the test, record the strain gage readings to determine the horizontal force.

1. Take static coefficient of friction readings at the instant of impending motion or slip between the surfaces in question. For flexible backed TFE (Teflon) bearings, measure strain at the point of maximum displacement.
2. Obtain kinetic coefficient of friction readings by taking the average reading while surfaces are sliding. Do this in both directions of movement.

### F. Calculations

$$f = \frac{F}{N}$$

Where:

F = Horizontal force due to friction or internal shear resistance (lbs).

N = Normal force (lbs).

f = Coefficient of friction

$f_s$ = static

$f_k$ = kinetic

Determine "F" from the strain gage indicator readings by use of calibration plot I (Figure III). Determine N from gage #2 (Figure II) by use of calibration plot II (Figure IV).

## REPORTING RESULTS

1. Report the following test results on test report Form HMR T-6028.

   a. Maximum static coefficient of friction.

   b. Average static coefficient of friction.

   c. Average kinetic coefficient of friction.

   d. Remarks concerning the specimen's appearance after completion of test, excessive wear, delamination, etc.

The "The maximum friction coefficient" as determined on Form HMR T-6028 is defined as the highest coefficient as averaged over any 50 cycles of the test.

The "Average friction coefficient" is defined as the average of at least 5 and not more than 10 readings taken between 2,000 and 8,000 cycles. These readings shall be taken at intervals of not less than 500 cycles apart.

**REFERENCE**

A California Method

**End of Text on Calif. 663-A**

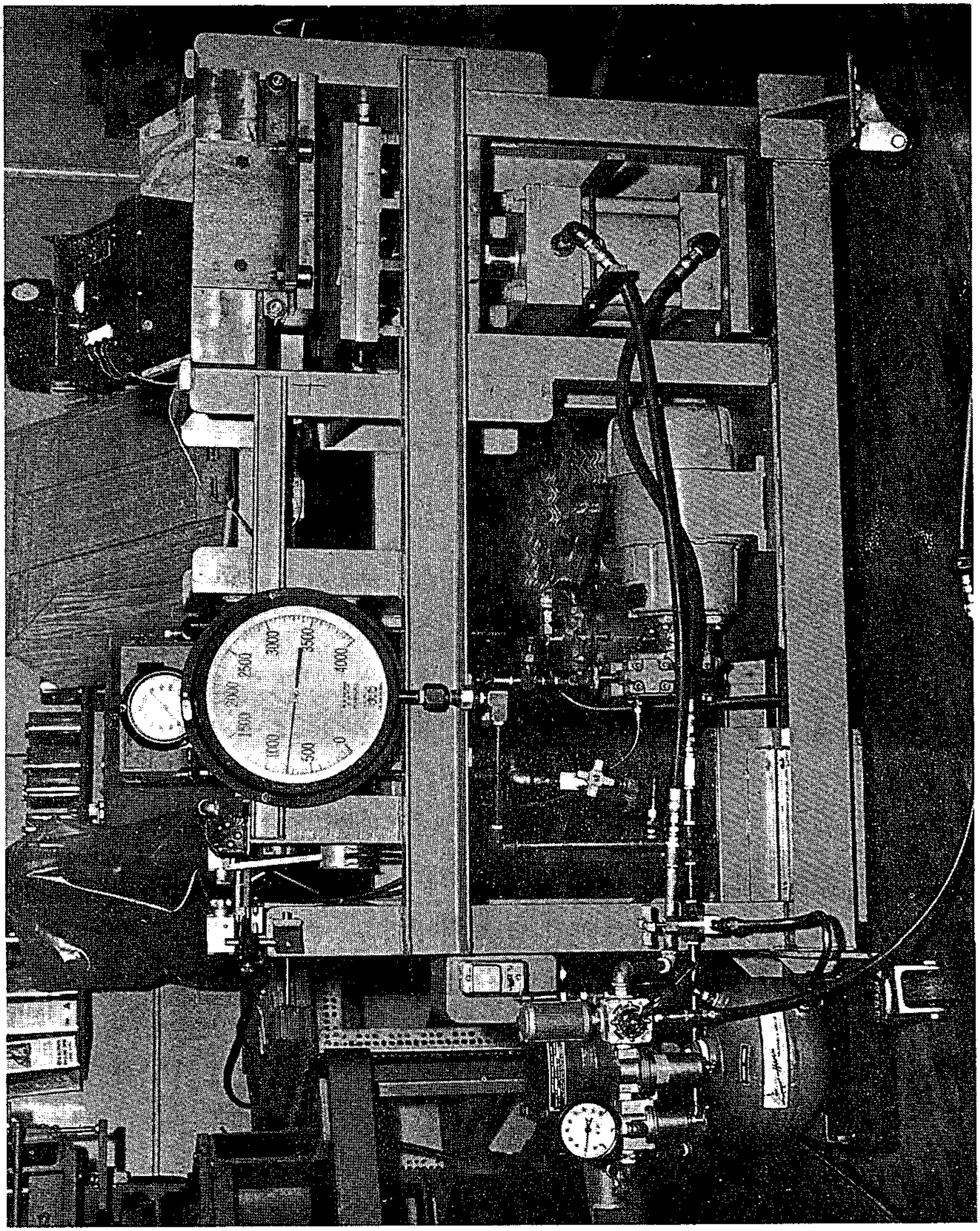


FIGURE 1

# SCHEMATIC DIAGRAM OF FATIGUE TESTING MACHINE

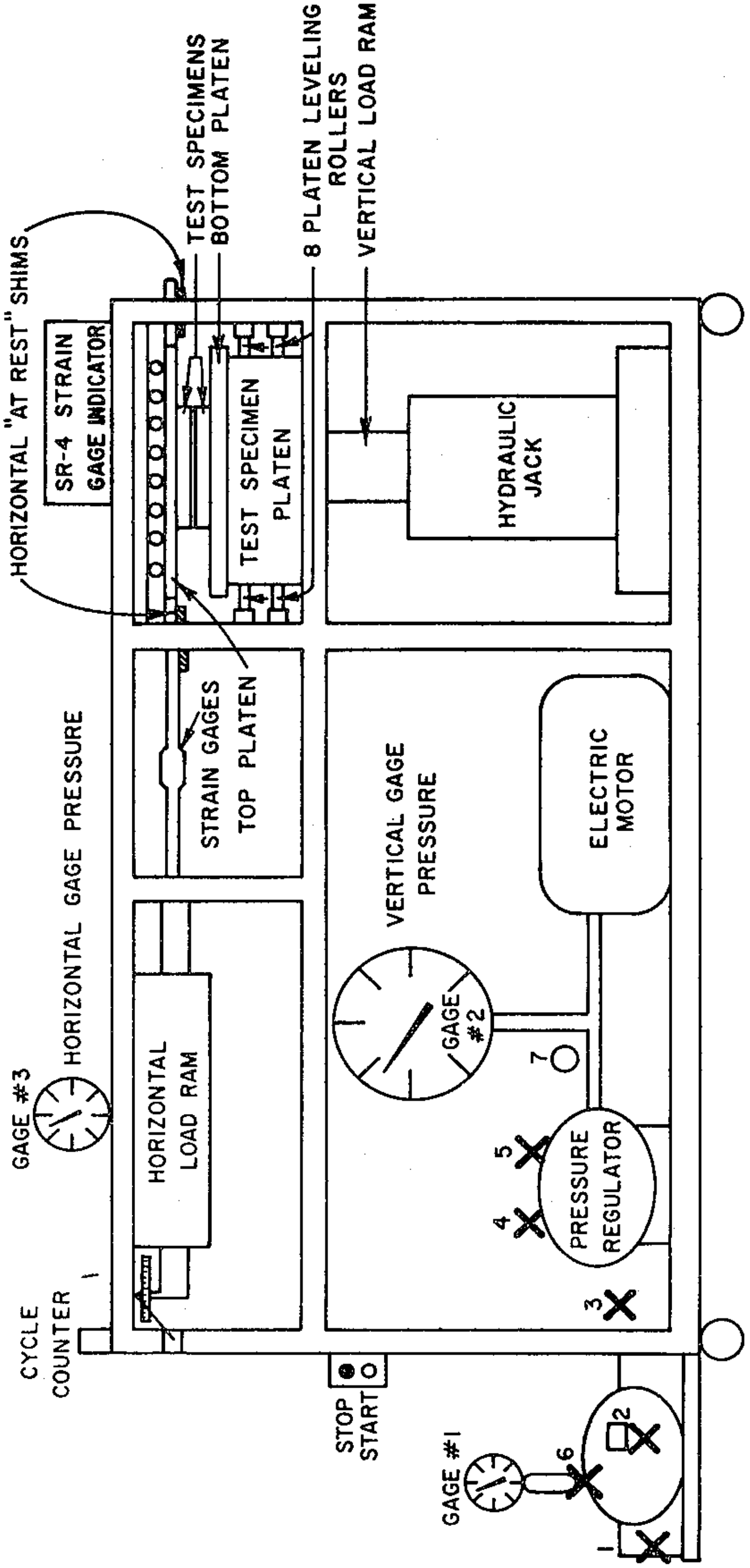



FIGURE II

## BEARING PAD FATIGUE TESTING MACHINE

### STRAIN GAGE CALIBRATION CURVE

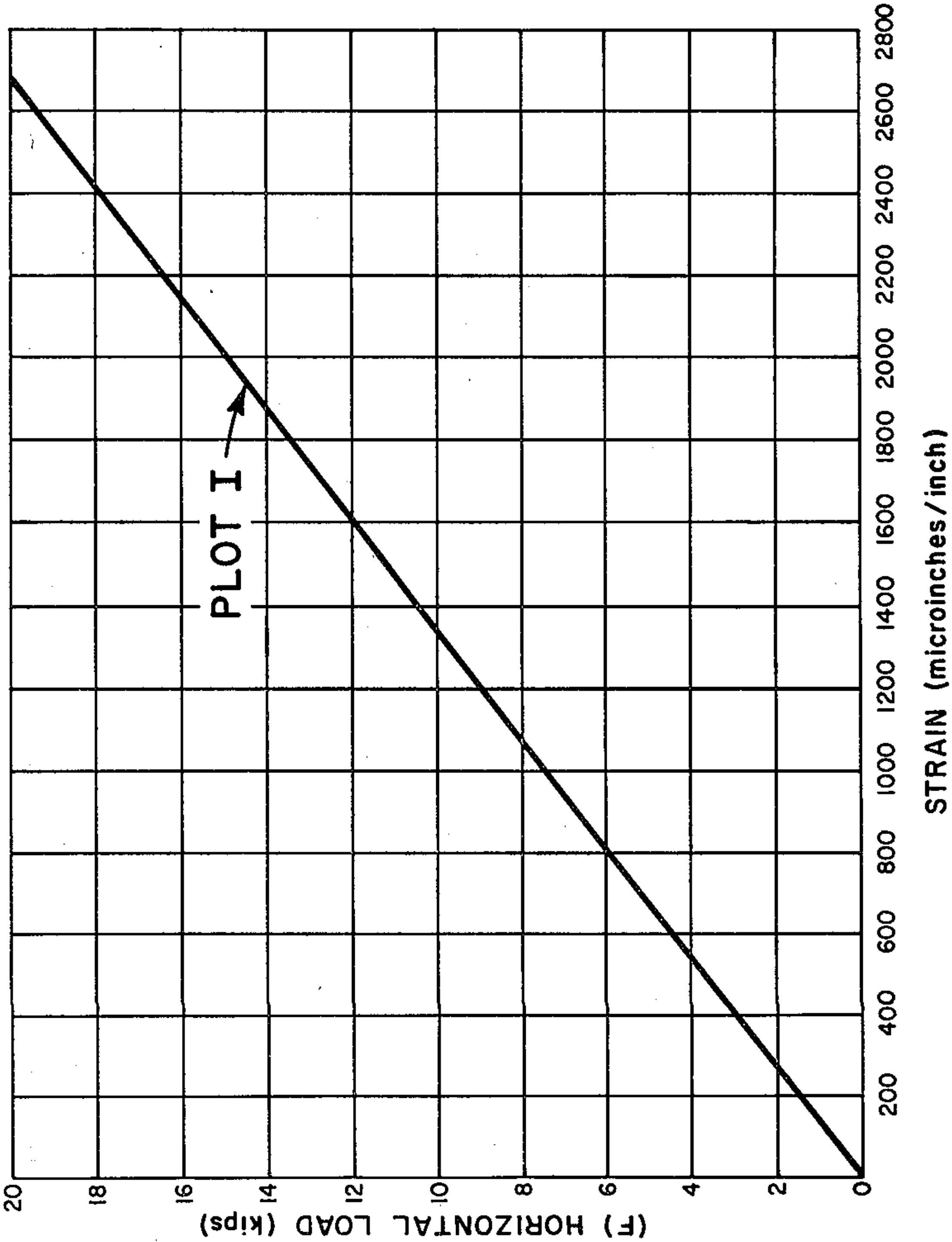



FIGURE III

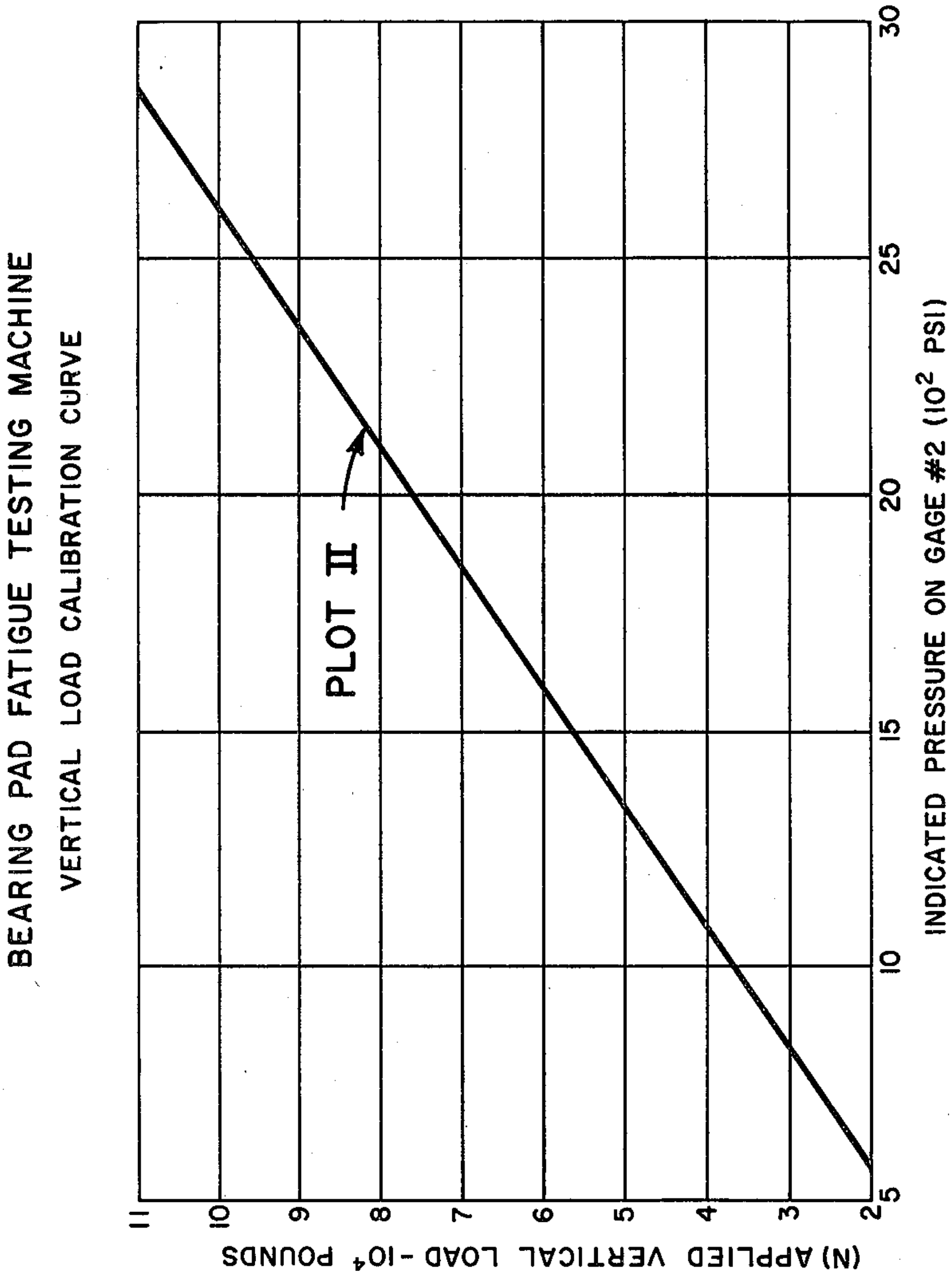

BEARING PAD FATIGUE TESTING MACHINE
VERTICAL LOAD CALIBRATION CURVE
PLOT II
INDICATED PRESSURE ON GAGE #2 (10² PSI)
(N) APPLIED VERTICAL LOAD - 10⁴ POUNDS
5
10
15
20
25
30
2
3
4
5
6
7
8
9
10
11

FIGURE IV

MATERIALS AND RESEARCH DEPARTMENT

# FATIGUE AND COEFFICIENT OF FRICTION TEST DATA SHEET

TYPE: ______________________________

SIZE: ______________________________

DATE: ______________ LOAD: ______________

STROKE: SPEED:

DRAWING OF SPECIMEN

| CYCLES | SPEED INCHES/ MINUTE | + READING | − READING | MOVING AVERAGE | GAGE PRESSURE | N KIPS | +f KIPS | −f KIPS | MOVING f KIPS | +u | −u | THICKNESS INCHES | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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HMR T-6028 (Orig. 11/66)

MIL-C-882C
26 September 1966
SUPERSEDING
MIL-C-882B
6 October 1966
(See 6.3)

MILITARY SPECIFICATION

# CLOTH, DUCK, COTTON SYNTHETIC RUBBER IMPREGNATED, AND LAMINATED, OIL RESISTANT

*This specification is mandatory for use by all Departments and Agencies of the Department of Defense.*

## 1. SCOPE

**1.1 Scope.** This specification covers laminated cotton duck cloth that has been impregnated with oil resistant synthetic rubber.

**1.2 Classification.** Cloth shall be of the following types as specified (see 6.1).

Type I — Sheets.
Type II — Strips.
Type III — Cut items.
Type IV — Molded items.

## 2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

### SPECIFICATIONS

FEDERAL

CCC-T-191 — Textile Test Methods.
PPP-B-576 — Box, Wood, Cleated, Veneer, Paper Overlaid.
PPP-B-585 — Boxes, Wood, Wirebound.
PPP-B-591 — Boxes, Fiberboard, Wood-Cleated.
PPP-B-601 — Boxes, Wood, Cleated-Plywood.
PPP-B-621 — Boxes, Wood, Nailed and Lock-Corner.
PPP-B-636 — Box, Fiberboard.
PPP-B-640 — Boxes, Fiberboard, Corrugated, Triple Wall.
PPP-T-76 — Tape, Pressure-Sensitive Adhesive Paper, (For Carton Sealing).
PPP-T-45 — Tape, Gummed Paper, Reinforced and Plain, For Sealing and Securing.

MILITARY

MIL-P-116 — Preservation, Methods of.
MIL-L-10547 — Liners, Case, and Sheet, Overwrap; Water-Vaporproof or Waterproof, Flexible.
MIL-F-16884 — Fuel Oil, Diesel, Marine.

FSC 8305

STANDARDS

FEDERAL

FED-STD-601 — Rubber: Sampling and Testing.

MILITARY

MIL-STD-129 — Marking for Shipment and Storage.
MIL-STD-289 — Visual Inspection Guide for Rubber Sheet Material.
MIL-STD-407 — Visual Inspection Guide for Rubber Molded Items.

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 **Other publications.** The following documents form a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

NATIONAL BUREAU OF STANDARD
Commercial Standard CS 227-59— Polyethylene Film

(Application for copies should be addressed to the Superintendent of Documents, Government Printing Office, Washington, D. C. 20402.)

OFFICIAL CLASSIFICATION COMMITTEE
Uniform Freight Classification Rules

(Application for copies should be addressed to the Official Classification Committee, 1 Park Avenue at 33rd Street, New York, New York 10016.)

(Technical society and technical association specifications and standards are generally available for reference from libraries. They are also distributed among technical groups and using Federal agencies.)

## 3. REQUIREMENTS

3.1 **Materials.**

3.1.1 *Duck.* The duck shall be of the highest quality cotton, and shall weigh a minimum of 8 ounces per square yard. The warp and the filling yarn shall be 2-ply. The filling count of the duck shall be 40 ± 2 threads per inch and the warp count shall be 50 ± 1 threads per inch.

3.1.2 *Synthetic rubber.* The synthetic rubber used for impregnating the cotton duck material shall be a compound which shall conform to the requirements of this specification.

3.2 **Form.** The form, dimensions and shapes for types I through IV shall be as specified (see 6.2).

3.2.1 *Tolerances.* Tolerances other than those listed in table I shall be as specified (see 6.2).

TABLE I. *Tolerances*

| All types | Type II | |
|---|---|---|
| Thickness | Width (inches) | Tolerances (plus or minus) |
| | | Inch |
| ± 5 percent | ¼ to ½, inclusive | 1/32 |
| | Over ½ to 1, inclusive | 3/64 |
| | Over 1 | 1/16 |

3.3 **Age.** The age of the impregnated cotton duck based on the month in which it is cured shall not exceed 12 months at the time of acceptance under contract by the purchaser. Material shall be rejected when the cure date cannot be determined.

3.4 **Physical requirements.** The laminated material shall conform to the following physical requirements:

3.4.1 *Density.* The density shall be a minimum of 67 pounds per cubic foot, when determined by the procedure specified in 4.4.2.

3.4.2 *Load deflection.* The material shall be within the deflection limits shown in table II, when tested as specified in 4.4.3.

**TABLE II. *Load deflection.***

| Load (psi) | 14/64 to 16/64 inch thick | | 17/64 to 19/64 inch thick | | 21/64 to 23/64 inch thick | | 15/32 to 17/32 inch thick | | 19/32 to 21/32 inch thick | | 61/64 to 67/64 inch thick | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Deflections of laminated material** | | | | | | | | | | | |
| | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum | Minimum | Maximum |
| | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch | Inch |
| 50 | 0.001 | 0.005 | 0.002 | 0.005 | 0.002 | 0.007 | 0.003 | 0.009 | 0.004 | 0.011 | 0.006 | 0.019 |
| 100 | .002 | .007 | .003 | .009 | .004 | .011 | .005 | .014 | .007 | .017 | .010 | .028 |
| 200 | .003 | .011 | .006 | .013 | .007 | .016 | .009 | .021 | .013 | .027 | .018 | .043 |
| 300 | .005 | .014 | .008 | .017 | .010 | .020 | .013 | .027 | .018 | .034 | .025 | .054 |
| 400 | .006 | .016 | .010 | .020 | .012 | .024 | .016 | .033 | .022 | .040 | .031 | .064 |
| 500 | .008 | .018 | .012 | .023 | .014 | .027 | .019 | .038 | .026 | .046 | .037 | .073 |
| 600 | .009 | .020 | .013 | .025 | .016 | .030 | .022 | .042 | .029 | .052 | .043 | .081 |
| 700 | .010 | .022 | .015 | .027 | .018 | .033 | .025 | .047 | .033 | .056 | .049 | .090 |
| 800 | .012 | .024 | .017 | .029 | .019 | .035 | .028 | .051 | .036 | .062 | .055 | .098 |
| 900 | .013 | .025 | .018 | .031 | .021 | .038 | .031 | .055 | .040 | .066 | .060 | .105 |
| 1,000 | .014 | .027 | .020 | .033 | .023 | .040 | .034 | .058 | .043 | .070 | .065 | .111 |
| 1,200 | .017 | .030 | .023 | .037 | .026 | .044 | .040 | .065 | .049 | .078 | .075 | .124 |
| 1,400 | .019 | .033 | .025 | .040 | .029 | .048 | .045 | .072 | .055 | .086 | .085 | .136 |
| 1,600 | .021 | .035 | .028 | .043 | .032 | .052 | .050 | .078 | .061 | .093 | .094 | .147 |
| 1,800 | .024 | .038 | .031 | .046 | .035 | .055 | .055 | .084 | .067 | .100 | .103 | .157 |
| 2,000 | .026 | .040 | .033 | .049 | .038 | .058 | .060 | .090 | .072 | .107 | .112 | .168 |

3.4.3 *Permanent set.* The permanent set of the laminated material, when determined by the method specified in 4.4.4, shall be no more than the following:

| *Compressive stress psi* | *Permanent set percent* |
|---|---|
| 500 | 3.0 |
| 1,000 | 4.0 |
| 3,000 | 7.0 |
| 5,000 | 10.0 |
| 10,000 | 13.0 |

3.4.4 *Oil resistance.*

3.4.4.1 *Delamination.* When the laminated material is tested as specified in 4.4.5.1, there shall be no delamination.

3.4.4.2 *Swell.* When the laminated material is subjected to the immersion test specified in 4.4.5.2, the volume swell shall be no more than 25 percent.

3.5 **Fungus resistance.** No fungus growth shall be apparent when tested in accordance with 4.4.6.

3.6 **Workmanship.** The finished material shall be clean, evenly laminated, and shall conform to the quality and grade of product established by this specification. The occurrence of defects shall not exceed the acceptance number specified.

## 4. QUALITY ASSURANCE PROVISIONS

4.1 **Responsibility for inspection.** Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Sampling for quality conformance inspection.

4.2.1 *Lot.* For purposes of quality conformance inspection, a lot shall consist of not more than 2,500 pounds of material of the same form and dimensions, produced in one plant under essentially the same conditions and offered for delivery at one time.

TABLE III. *Sampling for examination.*

| Lot size Number of cut or molded items, or unit areas of sheets or strips | Sample size Number of cut or molded items, or unit areas of sheets or strips | Number of nonconforming or defective pieces or unit areas | | | |
|---|---|---|---|---|---|
| | | Major defects | | Total defects | |
| | | Accept | Reject | Accept | Reject |
| Up to 8 | 5 | 0 | 1 | 0 | 1 |
| 9 to 15 | 7 | 0 | 1 | 0 | 1 |
| 16 to 25 | 10 | 0 | 1 | 1 | 2 |
| 26 to 40 | 15 | 0 | 1 | 1 | 2 |
| 41 to 65 | 15 | 1 | 2 | 2 | 3 |
| 66 to 110 | 20 | 1 | 2 | 2 | 3 |
| 111 to 180 | 25 | 1 | 2 | 3 | 4 |
| 181 to 500 | 35 | 2 | 3 | 5 | 6 |
| 501 to 800 | 50 | 3 | 4 | 6 | 7 |
| 801 to 1300 | 75 | 4 | 5 | 9 | 10 |
| 1301 to 3200 | 110 | 6 | 7 | 12 | 13 |
| 3201 and up | 150 | 8 | 9 | 17 | 18 |

4.2.1.1 *Cut and molded items.* The lot size shall be the number of cut or molded items in the lot.

4.2.1.2 *Sheets and strips.* The lot size shall be the number of unit areas in all sheets or strips of the lot. A unit area is defined as an area of one square foot; thus a sheet 2 feet wide and 20 feet long would be 40 units and a strip 4 inches wide by 20 feet long would be 7 units.

4.2.2 *Sampling for examination.* The sample size (number of samples to be selected from a lot and examined as specified in 4.3.1) shall be as specified in table III.

4.2.2.1 The specified samples shall be selected at random from the lot. The sampling of the sheet and strip material shall be divided among all rolls in the lot.

4.2.2.2 *Special sample.* There shall be furnished with each lot 1 foot of the cotton duck, the full width of the bolt, of the same material used in the manufacture of the lot.

4.2.3 *Sampling for tests.* Two sets of samples shall be taken from each lot in sufficient quantity to perform all tests specified in 4.3.2. The samples shall be taken from those selected in accordance with 4.2.2. No two samples shall be taken from the same sheet, strip, or cut or molded item. Where test specimens cannot be prepared from the items, the contractor shall furnish two samples each 6 by 6 by 0.5-inch thick. These pieces must be identical in composition and equivalent in cure, and prepared from material used in the lot of finished material offered for delivery.

4.3 Quality conformance inspection.

4.3.1 *Visual and dimensional examination.* Each of the sample pieces taken in accordance with 4.2.2 shall be subjected to surface examination for number of plies, workmanship, dimensions, and tolerances. MIL-STD-289 or MIL-STD-407 shall be used to determine and evaluate defects through visual examination. In addition the samples shall be examined for tackiness and brittleness. Any sample sheet, strip, cut, or molded part found not to be in accordance with this specification shall not be offered for delivery. If the number of nonconforming items exceeds the acceptance number specified in 4.2.2 for that sample, this shall be cause for rejection of the lot represented by the sample.

4.3.2 *Quality conformance tests.* Each set of samples selected in accordance with 4.2.3 shall be subjected to the tests specified in 4.4.2 through 4.4.6. If any sample fails to conform to this specification, this shall be cause for rejection of the entire lot represented by the sample.

4.3.2.1 *Special sample.* The sample piece of duck furnished in accordance with 4.2.2.2 shall be subjected to the tests specified in 4.4.1.

4.4 **Test procedures.**[1]

4.4.1 Thread count and weight of duck shall be determined in accordance with methods 5050 and 5041 respectively of CCC-T-191.

4.4.2 *Density.* The specific gravity shall be determined by the standard hydrostatic displacement, method 14011 of FED-STD-601. Density in pounds per cubic foot = specific gravity times 0.03613 times 1728.

4.4.3 *Load deflection.* The load deflection shall be determined as follows:

(a) Each specimen of impregnated cotton duck, 2 by 2 inches by the thickness of the material, shall be compressed, perpendicular to the direction of lamination, between two steel plates which are held rigidly parallel. The origin of deflection measurements shall be taken at a stress of 5 psi on the specimen.

(b) The load shall be increased at the rate of 500 pounds per minute and the deflection recorded at the specified load (see 3.4.2). The average deflection of 2 specimens shall be reported as the deflection at each specified load.

[1] Unless otherwise indicated in the test method, no tests shall be conducted prior to a conditioning period of the test specimen of 4 hours at room temperature 27° ± 5°C (80° ± 9°F). Sample preparation may be undertaken without regard to this time interval.

4.4.4 *Permanent set.* The permanent set shall be determined as follows:

(a) The specimen of impregnated cotton duck, 2 by 2 inches by the thickness of the material, shall be compressed, perpendicular to the direction of lamination between two steel plates under a preliminary load of 50 pounds per square inch for 5 minutes. This shall be considered the zero point.

(b) The load shall then be increased at the rate of 500 pounds per minute up to 500 pounds per square inch. The total load shall then be released. The loss in thickness shall be measured within 1 minute and expressed as a percentage of the original "zero point" thickness. The next higher specified load shall then be applied to the same specimen within 5 minutes of release except that no precondition-load shall be applied. The loss in height shall again be determined as a percentage of the original "zero point" thickness. This loading and unloading shall be repeated on the same specimens in duplicate to cover the range of permanent set determinations specified in 3.4.3. The average values of the two determinations shall be reported as the permanent set after the specified loads.

4.4.5 *Oil resistance.*

4.4.5.1 *Delamination.* The delamination test shall be in accordance with method 6811 of FED-STD-601, except that diesel oil in accordance with type I of MIL-F-16884 shall be used as the immersion medium.

4.4.5.2 *Volume swell.* The volume swell test shall be in accordance with method 6211 of FED-STD-601, except that the immersion period shall be 24 ± ¼ hours. The immersion medium shall be diesel oil in accordance with type I of MIL-F-16884.

4.4.6 *Fungus resistance.* Fungus resistance shall be determined by the qualitative procedure of method 5751 of CCC-T-191. The specimen shall be cut from the finished material and shall be the thickness of the material in the lot. Prior to inoculation, the specimen shall be heated at 149° ± 2.2° C. (300 ± 4° F.) for one hour and then cooled to room temperature.

**4.5 Examination of preparation for delivery.** An examination shall be made to determine that packaging, packing, contents, and markings comply with the requirements of this specification. The sample unit shall be one shipping container, fully packed selected just prior to the closing operation. Shipping containers fully prepared for delivery shall be examined for closure defects. sampling requirements shall be the same as specified for material in 4.2.2. but shall apply to unit containers and not the impregnated cotton duck.

| *Examine* | *Defect* |
|---|---|
| Packaging | Unit package not packaged as specified, not level specified. |
| | Packaging material not as specified. |
| | Closure not as specified. |
| Packing | Not in accordance with contract requirements. |
| | Container not as specified; closure not accompanied by specified or required methods or materials. |
| | Any nonconforming component, component missing, damaged or otherwise defective affecting serviceability. |
| | Inadequate application of components such as: incomplete closure and case liners, container flaps loose or inadequate strappings: bulged or distorted containers. |

| | |
|---|---|
| Count | Number of sheets per container less than specified or indicated quantity. |
| Weight | Gross weight exceeds specified requirements. |
| Markings | Interior or exterior markings (as applicable) omitted, illegible, incorrect, incomplete, or not in accordance with contract requirements. |

4.5.1 *Rejection.* A unit container found with a defect shall not be offered for delivery and if the number of defective units exceeds the acceptance number shown in table III, this shall be cause for rejection of the entire lot represented by the units.

5. PREPARATION FOR DELIVERY

5.1 Packaging. Packaging shall be level A or C as specified (see 6.2).

5.1.1 *Level A.* The laminated material shall be packaged as follows:

5.1.1.1 *Type I.* Unless otherwise specified (see 6.2), sheets shall be packaged as flat slabs not over 7 feet long and shall be sealed in seamless minimum 4 mil thick polyethylene tubing conforming to CS 227-59. The polyethylene shall be preferably heat sealed, but may be twisted and tied with plastic if desired.

5.1.1.2 *Type II.* Strips shall be individually coiled and sealed in polyethylene as specified in 5.1.1.1. Bagged coiled strips shall then be intermediate packaged in fiberboard boxes conforming to style RSC, type CF of PPP-B-636. The gross weight shall not exceed 50 pounds.

5.1.1.3 *Type III and IV.* Cut or molded items shall be bulk bagged in polyethylene as specified in 5.1.1.1. Bagged items shall then be intermediate packaged in fiberboard boxes conforming to style RSC type CF of PPP-B-636. The gross weight shall not exceed 50 pounds.

5.1.2 *Level C.* Packaging shall be sufficient to afford adequate protection against deterioration and physical damage during shipment from the supply source to the first receiving activity for early installation and may conform to the supplier's commercial practice.

5.2 Packing. Packing shall be level A, B or C as specified (see 6.2).

5.2.1 *Level A.* The material packaged as specified (see 6.2), shall be packed in containers conforming to any one of the following specifications at the option of the contractor:

| *Specification* | *Box* | *Classification* |
|---|---|---|
| PPP-B-576 | Wood-cleated, Veneer paper overlaid | Class 2 |
| PPP-B-591 | Fiberboard, Wood-cleated | Overseas type |
| PPP-B-601 | Wood, Cleated-plywood | Overseas type |
| PPP-B-636 | Fiberboard | Weather resistant |
| PPP-B-640 | Fiberboard-corrugated triple wall | Class 2 |

Shipping containers shall have caseliners conforming to MIL-L-10547 and shall be closed and sealed in accordance with the appendix of that specification. Caseliners for fiberboard boxes, conforming to PPP-B-636 and PPP-B-640, may be omitted provided all center and edge seams and manufacturer's joint are sealed and waterproofed with pressure sensitive tape in accordance with the applicable fiberboard box specification. Shipping containers shall be closed, strapped or banded in accordance with the applicable box specification or appendix thereto. The gross weight of wood, wood-cleated, and triple-wall boxes should not exceed 250 pounds. If the gross weight of a shipping container exceeds 250 pounds, it shall be modified to include a skid type base. Containers conforming to PPP-B-636 shall not exceed the weight limitations of the specification.

Intermediate fiberboard containers conforming to weather resistant Class of PPP-B-636 closed, sealed and banded as specified herein may be used as the shipping container and need not be over packed.

5.2.2 *Level B.* The laminated material packaged as specified (see 6.2), shall be packed in containers conforming to any one of the following specifications at the option of the contractor:

| *Specification* | *Box* | *Classification* |
|---|---|---|
| PPP-B-576 | Wood-cleated, Veneer paper overlaid | Class 1 |
| PPP-B-591 | Fiberboard, wood-cleated | Domestic type |
| PPP-B-601 | Wood, cleated-plywood | Domestic type |
| PPP-B-636 | Fiberboard | Domestic type |
| PPP-B-640 | Fiberboard-corrugated triple wall | Class 2 |

Shipping containers shall be closed, strapped or banded in accordance with the applicable container specification or appendix thereto, except that fiberboard containers may be sealed with tape in accordance with PPP-T-45. The gross weight of wood, wood-cleated and triple wall containers shall not exceed 250 pounds.

Containers conforming to PPP-B-636 containers shall not exceed the weight limitations of the specification. Intermediate fiberboard containers conforming to PPP-B-636, closed, sealed and banded as specified herein may be used as the shipping container and need not be overpacked.

5.2.3 *Level C.* The laminated material packaged as specified (see 6.2), shall be packed in a manner which will insure acceptance by common carrier, at lowest rate and will afford protection against physical or mechanical damage during direct shipment from the supply source to the first receiving activity for early installation. The shipping containers or method of packing shall conform to the Uniform Freight Classification Rules and Regulations or other carrier regulations as applicable to the mode of transportation and may be the supplier's commercial practice.

5.3 **Marking.** In addition to any special marking required by the contract or order, interior and exterior shipping containers shall be marked with the date (month and year) of cure and in accordance with MIL-STD-129.

## 6. NOTES

6.1 **Intended use.** The laminated cotton duck covered by this specification is intended for use in vibration attenuation.

6.2 **Ordering data.** Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type material required (see 3.2), and dimensions, tolerances and shape, as applicable (see 3.2 and 3.2.1).
(c) Selection of applicable level of packaging and packing required (see 5.1 and 5.2).

6.3 **Changes from previous issue.** The extent of changes (deletions, additions, etc.) preclude the annotation of the individual changes from the previous issue of this document.

**Custodians:**
Navy — SH
Air Force — 67

**Review activities:**
Navy — SH
Air Force — 67

**Preparing activity:**
Navy — SH
Project 8305-0424

☆ U. S. GOVERNMENT PRINTING OFFICE: 1966—251-068—(X75)