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Evaluation of Several Brands of Anaerobic Threadlocking Compounds Used for Various Bolting Applications

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16. ABSTRACT

Caltrans has various bolting applications using different diameter bolt sizes and materials. In some cases an Anaerobic Threadlocking Compound is more suitable for securing the nut on a bolt. The 1999, Caltrans "List of Approved Threadlocking Compounds" refers to only 25.4 mm (1") diameter hot-dipped galvanized threaded rods with a matching ASTM A563, Grade DH nuts. These results did not cover the various sizes and materials that could be used for Anaerobic Threadlocking Compounds.

Caltrans tested five different anaerobic threadlocking products on various bolting applications. The tests were completed with different diameter bolts made from different types of materials to see if they would produce breaking torque and prevailing torque values that are similar to the values obtained in 1999. The tested products were manufactured by Loctite Pro-Lock Division, Permabond International, Hernon Manufacturing Inc., Saf-T-Lok, and Pacer Inc. Four of the five brands of the anaerobic threadlocking compounds tested had a breaking torque higher than 61 Nm (45 lb ft). The only deviation from this was the breaking torque for Pacer brand when used in the stainless steel application. However, the prevailing torque average of 369 Nm (272 lb ft) was high enough to allow the use of Pacer in this application. These results can only be assured if all traces of oil, debris, and dry lubricants are thoroughly removed from all threaded surfaces prior to application of the primer or adhesives.

This study produced a list of threadlocking compounds that are approved for use only for each particular size and type.

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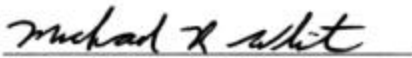
Evaluation of Several Brands of Anaerobic Threadlocking Compounds
used for Various Bolting Applications

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Conversion Factors

Torque:

To convert Newton-meter (N·m) to pound-foot (lb·ft) multiply (N·m) by 0.7376.

To convert pound-foot (lb·ft) to Newton-meter (N·m) multiply (lb·ft) by 1.3558.

Note that both lb·ft and ft·lb are used as units of torque. Most torque wrenches are labeled with, or report results in, ft·lb. In the U.S customary system of units a moment of force (torque) should be reported as lb·ft while a force acting over a distance (work) is reported as ft·lb.

Temperature:

To convert degrees Celsius (°C) to degrees Fahrenheit (°F), multiply °C by 1.8 and add 32.

To convert degrees Fahrenheit (°F) to degrees Celsius (°C), subtract 32 from °F and divide that result by 1.8.

Force:

To convert Newton (N) to pounds (lb) multiply (N) by 0.22481.

To convert pounds (lb) to Newton (N) multiply (lb) by 4.4482.

Length:

To convert meters (m) to feet (ft) multiply (m) by 3.2808.

To convert feet (ft) to meters (m) multiply (ft) by 0.3048.

To convert meters (m) to inches (in) multiply (m) by 39.3701.

To convert inches (in) to meters (m) multiply (in) by 0.0254.

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TABLE OF CONTENTS

TOPIC	PAGE
Technical Report Standard Title Page	ii
Disclaimer.....	iii
Metric Conversion Information.....	iv
Research Staff and Acknowledgements	v
Table of Contents.....	vi
List of Figures	vii
List of Tables	vii
1. INTRODUCTION.....	1-2
1.1 Overview of Report Contents	1
1.2 Problem Statement	1
1.3 Background.....	1
1.4 Literature Search.....	1
1.5 Objective and Scope	1
1.6 Benefits	2
2. TECHNICAL DISCUSSION	2-9
2.1 Products.....	2-3
2.2 Test Facility.....	3
2.3 Test Equipment.....	3
2.4 Specimen Preparation.....	3-6
2.4.1 Clean Threads	6
2.4.2 Prime Threads	6
2.4.3 Bond Threads.....	6
2.4.4 Adjust Nut	6
2.5 Test Method.....	7
2.6 Test Results.....	7-8
2.7 Evaluation.....	9
3. CONCLUSIONS and RECOMMENDATIONS.....	9
3.1 Future Research	9
4. IMPLEMENTATION.....	9
5. REFERENCES	10
6. APPENDICES	10-C1
A Pre-Qualified Products List (QPL) Website	A1-A2
B Approved Systems	B1
C Application Instructions	C1

LIST OF FIGURES

FIGURE	PAGE
1. Some of the purchased Anaerobic Threadlocking Compounds and primers	2
2. 38.1mm x 101.6mm (1-1/2"x4") long A325 plain bolts in 50.8mm (2") deep tapped holes in a 63.5mm (2-1/2") thick steel plate, no pre-tension.....	4
3. 25.4mm x 101.6mm (1" x 4") long A325 plain bolts with matching A194 Grade 2H nuts.....	4
4. 22.2mm x 101.6mm (7/8" – 9 UNC x 4") long A193 Grade B8 (Type 304 SS) plain bolts with matching A194 Grade 8 (Type 304 SS) Heavy Hex nuts.....	5
5. 38.1mm (1-1/2") A325 plain bolts with matching A194, Grade 2H, plain nuts	5
6. 31.75mm (1-1/4") A325, Type 1, HDG bolts with matching A563, Grade DH, HDG nuts	6

LIST OF TABLES – TEST RESULTS

TABLE	PAGE
1. Test Series 1, 38.1mm x 101.6mm (1-1/2"x4") long A325 plain bolts in 50.8mm (2") deep tapped holes in a 63.5mm (2-1/2") thick steel plate, no pre-tension.....	7
2. Test Series 2, 25.4mm x 101.6mm (1" x 4") long A325 plain bolts with matching A194 Grade 2H nuts	7
3. Test Series 3, 22.2mm x 101.6mm (7/8" – 9 UNC x 4") long A193 Grade B8 (Type 304 SS) plain bolts with matching A194 Grade 8 (Type 304 SS) Heavy Hex nuts	8
4. Test Series 4, 38.1mm (1-1/2") A325 plain bolts with matching A194, Grade 2H, plain nuts.....	8
5. Test Series 5, 31.75mm (1-1/4") A325, Type 1, HDG bolts with matching A563, Grade DH, HDG nuts	8

1. INTRODUCTION

In 1992 and 1999 a series of tests were performed on anaerobic threadlocking compounds applied to a 25.4mm (1") diameter ASTM A449 hot-dipped galvanized threaded rod with a matching ASTM A563, Grade DH nut. The results produced a list of Caltrans approved anaerobic threadlocking compounds from which designers and crews could use as a source list for that specific size and material type. Unfortunately, these results did not cover the various bolting applications with different diameter sizes and materials that could be used by the anaerobic threadlocking compounds.

1.1 Overview of Report Contents

This report describes the problems related to the lack of tests performed on various bolting applications using anaerobic threadlocking compounds with different diameter sizes and different types of materials. The report also lists the products that were tested in hopes of producing an approved list that can be used by designers and crews. These products were tested from representative samples. Those that provided an acceptable level of breaking torque were approved and posted on the Caltrans Website under the Pre-Qualified Products List (QPL) in the "Anaerobic Threadlocking Compounds" section. This report also makes recommendations that may be incorporated into future Caltrans Standard Specifications.

1.2 Problem Statement

A list is needed for approved anaerobic threadlocking compounds for various bolting applications on bridge structures, using different diameter bolts with different types of materials.

1.3 Background

After the results of the Caltrans 1999 Anaerobic Threadlocking Compound research project on a 25.4mm (1") diameter ASTM A449 hot-dipped galvanized threaded rod with a matching ASTM A563, Grade DH nut, maintenance crews were requesting new tests be conducted for various bolting applications using different diameter bolt sizes and different types of materials with the anaerobic threadlocking compounds.

The original scope of this project was based on a request by the Structures Representatives on the Benicia-Martinez Bridge to test only the ASTM Designation A325 Plain bolts in blind tapped holes in steel plates. After the research project was approved and funding was set, the same representative discovered other bolting situations on the same structure that required the use of threadlocking compounds. It was requested that the scope from the original project be expanded to allow inclusion of these other bolting applications.

1.4 Literature Search

A literature search was not deemed necessary due to the simple nature of the proposed testing and the time constraints involved.

1.5 Objective and Scope

The objective of this minor research project was to produce a list of approved anaerobic threadlocking compounds for various bolting applications. This was accomplished by evaluating the performance of several anaerobic threadlocking compounds. These compounds were tested to see if they could provide a breaking torque similar to, or higher than, those obtained in the testing done in 1999. The breaking torque value is 61 N·m (45 lb-ft) and it was used as a base value for these tests because there have not been any significant problems with the cable restrainer nuts migrating under

normal service conditions.

1.6 Benefits

The main benefit of this research project was to provide a list of approved anaerobic threadlocking compounds for use by designers and crews for various bolting applications. Information gathered might also be useful in other areas where Caltrans has the need to secure nuts onto threaded bolts or rods. It is important to note that this information applies only to the same type and size of threaded bolts.

Warning: Care must be taken to ensure that the resulting list of approved anaerobic threadlocking compounds is not used in applications that are significantly different from those tested here. The breaking torque expected in this research project may vary significantly from other types of fasteners based on variables such as; lubrication, nut-to-rod clearances, finishes such as galvanized or plain, or non-finished stainless steels, and whether or not the nut (or bolt) is torqued down against a positive stop.

2. TECHNICAL DISCUSSION

2.1 Products

Caltrans purchased five different anaerobic threadlocking compounds from their respective vendors. Figure-1, below, shows some of the purchased compounds and primers.

Figure-1 Some of the purchased Anaerobic Threadlocking Compounds and primers.

These products are:

1. Loctite Pro-Lock Division
 - a) Loctite 7070 Cleaner. Part No. 22355
 - b) Pro-Lock “Klean-N-Prime.” Part No. 30566
 - c) Pro-Lock High Strength Threadlocker. Part No. 81792
2. Permabond International
 - a) Perma-Lok Anaerobic Surface Conditioner. Part No. ASC10
 - b) Perma-Lok Heavy Duty Bolt and Stud Locking Anaerobic Adhesive/Sealant. Part No. HH120
3. Hernon Manufacturing, Inc.
 - a) Hernon Cleaner. Part No. EF-62
 - b) Hernon Primer. Part No. EF-49
 - c) Hernon Nuts N’ Bolts Anaerobic Adhesive. Part No. 429
4. Saf-T-Lok

- a) Primer T. Part No. 19166
- b) T77 High Strength Anaerobic Adhesive. Part No. 27741

5. Hernon Manufacturing, Inc.

- a) Primer. Part No. 580-031
- b) ANL-77 Anaerobic Adhesive. Part No. 560-073

2.2 Test Facility

All testing related to this research project were conducted at the Transportation Laboratory (Translab) of the California Department of Transportation in Sacramento, California.

2.3 Test Equipment

The torque required to break the nuts free was applied using a Mitutoyo brand digital torque wrench with a range of 0 to 340 N·m (251 lb·ft), and a Consolidated Devices Inc. brand dial-type torque wrench with a range of 0 to 1355 N·m (1000 lb·ft).

2.4 Specimen Preparation

Five Test series were performed with different bolting methods, different diameter sizes, and different types of materials as listed below.

Test series 1, consisted of 38.1mm x 101.6mm (1-1/2"x4") long A325 plain bolts in 50.8mm (2") deep tapped holes in a 63.5mm (2-1/2") thick steel plate, no pre-tension as shown in Figure-2.

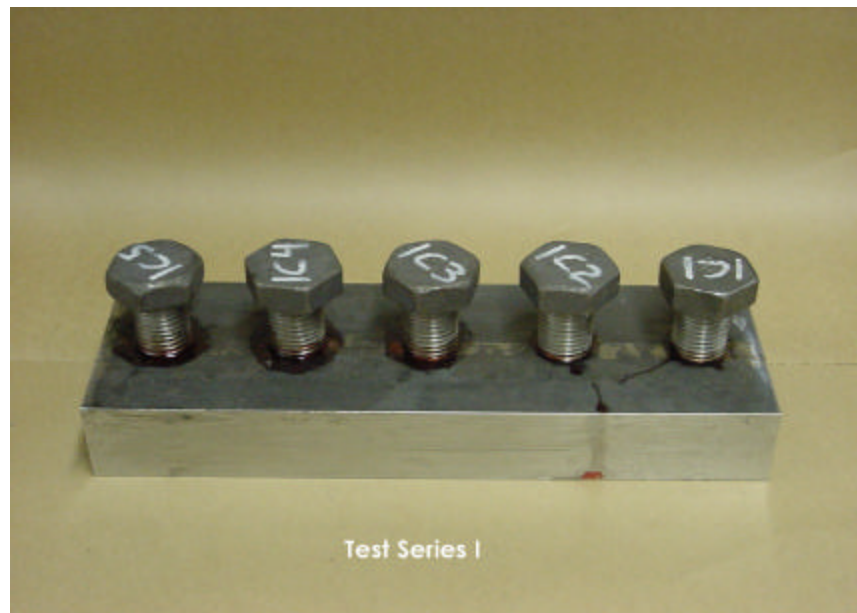


Figure-2 38.1mm x 101.6mm (1-1/2"x4") long A325 plain bolts in 50.8mm (2") deep tapped "blind" holes in a 63.5mm (2-1/2") thick steel plate, no pre-tension.

Test series 2, consisted of 25.4mm x 101.6mm (1" x 4") long A325 plain bolts with matching

A194 Grade 2H nuts as shown in Figure-3 below.



Figure-3 25.4mm x 101.6mm (1" x 4") long A325 plain
Bolts with matching A194 Grade 2H nuts

Test series 3, consisted of 22.2mm x 101.6mm (7/8" – 9 UNC x 4") long A193 Grade B8 (Type 304 SS) plain bolts with matching A194 Grade 8 (Type 304 SS) Heavy Hex nuts as shown in Figure-4 below.



Figure-4 22.2mm x 101.6mm (7/8" – 9 UNC x 4") long A193 Grade B8 (Type 304 SS) plain bolts
with matching A194 Grade 8 (Type 304 SS) Heavy Hex nuts

Test series 4, consisted of 38.1mm (1-1/2") A325 plain bolts with matching A194, Grade 2H, plain nuts as shown in Figure-5 below.



Figure-5 38.1mm (1-1/2") A325 plain bolts with matching A194, Grade 2H, plain nuts

Test series 5, consisted of 31.75mm (1-1/4") A325, Type 1, Hot-dipped Galvanized (HDG) bolts with matching A563, Grade DH, HDG nuts as shown in Figure-6 below.



Figure-6 31.75mm (1-1/4") A325, Type 1, HDG bolts with matching A563, Grade DH, HDG nuts

For each test series, five specimens were assembled for each of the five different threadlocking compound. The following instructions were used to secure the nut onto the threaded bolt. In the event of conflict between these instructions and those of a manufacturer, the manufacturer's instructions shall take precedence.

2.4.1 Clean Threads

Clean bolt and nut threads using the cleaning agent supplied with the corresponding threadlocking compound or with acetone. Use a small wire brush to remove all traces of oil and debris from the threads of both the bolt and nut.

2.4.2 Prime Threads

Apply the primer (supplied by the thread locker manufacturer per the provided instructions) to the threads of both the bolt and the nut.

2.4.3 Bond Threads

Apply the threadlocker compound per the instructions provided by the manufacturer onto the bolt and nut threads.

2.4.4 Adjust Nut

Thread the nut onto the bolt to the desired location by turning in one full turn and then backing it out one-half turn. Continue this procedure until the nut is at the desired final location on the bolt. This will ensure complete coverage of the threads.

2.5 Test Method

The test method used to evaluate these threadlocking compounds is very similar to that contained in ASTM D 5649-94 "Standard Test Method for Torque Strength of Adhesives used on Threaded Fasteners." The minor deviations involved do not affect or invalidate the results.

After the curing period, the maximum torque required to initiate unseating movement of the nut on the threaded rod was recorded with either a dial or digital torque wrench (click type torque wrenches cannot be used for this testing). This number was recorded as the "breaking torque." Another torque reading was taken as the nut was rotated through 180 degrees and this number was recorded as the "prevailing torque."

2.6 Test Results

Four of the five tested anaerobic threadlocking compound brands had an average breaking torque that was higher than the desired 61 N·m (45 lb·ft) for all applications when the nut is properly cleaned of all traces of the dry lubricant applied by the nut manufacturer. The only deviation from this was the breaking torque for Pacer brand when used in the stainless steel application. However, the prevailing torque average of 369 N·m (272 lb·ft) was high enough to allow the use of Pacer in this application. The specific results for each manufacturer are listed in Table-1 through Table-5, below.

Table-1. Test results for Test Series 1.
38.1mm x 101.6mm (1-1/2"x4") long A325 plain bolts in 50.8mm (2") deep
tapped holes in a 63.5mm (2-1/2") thick steel plate, no pre-tension

Manufacturer	Breaking Torque - N·m						Prevailing Torque - N·m					
	Sample No.						Sample No.					
	1	2	3	4	5	Avg	1	2	3	4	5	Avg
Loctite Pro-Lock Division	X	X	X	X	X	X	ND	ND	ND	ND	ND	
Permabond International	X	X	X	X	X	X	ND	ND	ND	ND	ND	
Hernon Manufacturing, Inc.	X	X	X	X	X	X	ND	ND	ND	ND	ND	
Saf T Lok	X	X	X	X	X	X	ND	ND	ND	ND	ND	
Pacer	X	X	X	X	X	X	ND	ND	ND	ND	ND	

X = exceeded the 1355 N·m(1000 lb·ft) capacity of the available torque wrench being used.

ND = Not Done

Table-2. Test results for Test Series 2.
25.4mm x 101.6mm (1" x 4") long A325 plain bolt with matching A194 Grade 2H nut.

Manufacturer	Breaking Torque - N·m						Prevailing Torque - N·m					
	Sample No.						Sample No.					
	1	2	3	4	5	Avg	1	2	3	4	5	Avg
Loctite Pro-Lock Division	881	868	990	868	868	895	416	578	720	826	704	649
Permabond International	870	583	868	719	624	733	568	434	563	587	605	551
Hernon Manufacturing, Inc.	515	597	664	475	705	591	705	620	537	357	616	567
Saf T Lok	678	719	686	691	709	697	477	438	438	447	503	461

Pacer	339	230	244	244	230	257	454	765	458	NC	568	449
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Table-3. Test results for Test Series 3.

22.2mm x 101.6mm (7/8" – 9 UNC x 4") long A193 Grade B8 (Type 304 SS) plain bolt with matching A194 Grade 8 (Type 304 SS) Heavy Hex nut.

Manufacturer	Breaking Torque - N·m						Prevailing Torque - N·m					
	Sample No.						Sample No.					
	1	2	3	4	5	Avg	1	2	3	4	5	Avg
Loctite Pro-Lock Division	285	285	285	258	258	274	339	420	237	190	230	283
Permabond International	122	122	163	122	108	127	542	434	461	373	285	419
Hernon Manufacturing, Inc.	285	271	285	244	312	279	325	217	271	325	339	296
Saf T Lok	190	149	217	149	190	179	420	502	420	447	529	464
Pacer	68	27	27	41	108	54	393	515	217	447	271	369

Table-4. Test results for Test Series 4.

38.1mm (1-1/2") A325 plain bolts with matching A194, Grade 2H, plain nuts.

Manufacturer	Breaking Torque - N·m						Prevailing Torque - N·m					
	Sample No.						Sample No.					
	1	2	3	4	5	Avg	1	2	3	4	5	Avg
Loctite Pro-Lock Division	x	x	x	x	x		DD	ND	ND	ND	ND	
Permabond International	640	393	475	136	373	403	x	x	x	x	x	
Hernon Manufacturing, Inc.	x	x	x	ND	ND		ND	ND	ND	ND	ND	
Saf T Lok	687	461	529	568	339	517	x	x	x	x	x	
Pacer	664	691	858	881	475	714	x	x	x	x	x	

X = exceeded the 1355 N·m(1000 lb·ft) capacity of the available torques wrench being used.

ND = Not Done

DD = Difficult to Determine

Table-5. Test results for Test Series 5.

31.75mm (1-1/4") A325, Type 1, HDG bolts with matching A563, Grade DH, HDG nuts.

Manufacturer	Breaking Torque - N·m						Prevailing Torque - N·m					
	Sample No.						Sample No.					
	1	2	3	4	5	Avg	1	2	3	4	5	Avg
Loctite Pro-Lock Division	786	922	796	827	x	886	529	601	519	582	758	598
Permabond International	515	475	369	548	237	429	274	407	371	382	378	363

Hernon Manufacturing, Inc.	502	555	881	678	881	699	502	277	354	384	319	367
Saf T Lok	746	298	298	556	475	475	485	277	302	296	371	346
Pacer	339	475	339	393	746	458	376	296	312	232	328	309

2.7 Evaluation

All five of the anaerobic threadlocking compounds tested had average breaking torque or prevailing torque values that were acceptable. These results can only be assured if all traces of oils, debris, and dry lubricants are thoroughly removed from all threaded surfaces prior to application of the primer or adhesives.

3. CONCLUSIONS and RECOMMENDATIONS

The five brands of anaerobic threadlocking compounds tested should provide breaking or prevailing torque values high enough to prevent the nut from becoming loose on the threaded bolt or migrating.

The following recommendations are made as a result of this project:

1. The information pertaining to threadlocking compounds contained under the Pre-Qualified Products List (QPL) section of the above mentioned Caltrans website should be maintained and updated as the need arises.
2. The list of approved threadlocking compounds should be made available to the current (and future) anaerobic threadlocking manufacturers as well as made available to anyone through the Caltrans website.
3. The contents of Appendix A should be submitted to the Caltrans Specifications Unit for possible inclusion in the current SSP as well as incorporation into the next Standard Specifications.

3.1 Future Research

Designers and crews may still have a need to use different bolt sizes and different materials that have not been properly tested for bolting applications using the anaerobic threadlocking compound. Should the need arise; further research and testing may be carried out.

4. IMPLEMENTATION

A list of approved threadlocking compounds and an installation procedure were developed from the results of this project and are included here as Appendix A. This same information was made available to designers and crews for immediate use for the specified bolting application. This information was also placed on the Caltrans website as part of the Pre-Qualified Products List (QPL) under the “Anaerobic Threadlocking Compounds” section:

http://www.dot.ca.gov/hq/esc/approved_products_list/threadlock.html.

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4. *Standard Test Method for Torque Strength of Adhesives Used on Threaded Fasteners*, ASTM D 5649-94. 1995 Annual Book of ASTM Standards, Volume 15.06, American Society for Testing and Materials, Philadelphia, 1995.

6. APPENDICES

- A Pre-Qualified Products List (QPL) website
- B Approved Systems
- C Application Instructions

Appendix A

Caltrans Approved Threadlocking Systems to be used only for those particular size and material type.

This 3 page document lists the Caltrans approved threadlocking products as well as installation instructions and is intended to be updated on the current approved list. This information should either be incorporated directly into the latest Standard Special Provision (SSP), 75-610_B09-21-99 or the web address mentioned below should be listed in the SSP.

The most recent version of this information will be maintained on the Pre-Qualified Products List (QPL) on the Caltrans Website. The address for the QPL is:

http://www.dot.ca.gov/hq/esc/approved_products_list/

Once there, click on the hypertext, which reads "Anaerobic Threadlocking Compounds."

CALTRANS-APPROVED
ANAEROBIC THREADLOCKING SYSTEMS

When required, one of the following approved chemical anaerobic threadlocking systems shall be used for any of the following:

1. 25.4mm (1") ASTM A 449 hot-dipped galvanized threaded rod with a matching ASTM A 563, Grade DH nut.
2. 38.1mm x 101.6mm (1-1/2"x4") long A325 plain bolts in 50.8mm (2") deep tapped holes in a 63.5mm (2-1/2") thick steel plate, no pre-tension.
3. 25.4mm x 101.6mm (1" x 4") long A325 plain bolts with matching A194 Grade 2H nuts,
4. 22.2mm x 101.6mm (7/8" – 9 UNC x 4") long A193 Grade B8 (Type 304 SS) plain bolts with matching A194 Grade 8 (Type 304 SS) Heavy Hex nuts,
5. 38.1mm (1-1/2") A325 plain bolts with matching A194, Grade 2H, plain nuts,
6. 31.75mm (1-1/4") A325, Type 1, HDG bolts with matching A563, Grade DH, HDG nuts.

These systems have been tested and approved for use only for those of specific type and size. Other applications may require different components and application procedures. Consult Jarvis Mahe at (916) 227-7076 if you wish to use these products for applications other than that stated above.

Each of these Caltrans-approved anaerobic threadlocking systems has three required components:

- 1) **CLEANER** - to clean lubricant and oils from the threads of the stud and nut.
- 2) **PRIMER** - to promote rapid curing of the anaerobic compound and to minimize migration of compound on threads.
- 3) **ANAEROBIC THREADLOCKER ADHESIVE** - to secure nut onto stud by filling the gap between nut and stud threads. Note: Anaerobic threadlocker adhesive compounds will set only where no oxygen is available.

Appendix B

**TABLE 1.
APPROVED ANAEROBIC THREADLOCKING SYSTEMS**

Manufacturer Information	Component	Trade Name	Part No.
1. Loctite Pro-Lock Division 1001 Trout Brook Crossing Rock Hill, CT 06067-3910 (800) 562-8483 www.loctite.com	Cleaner	ODC-Free Cleaner & Degreaser (Formerly 7070 cleaner)	22355
	Primer	Pro-Lock “Klean-N-Prime”	30566
	Adhesive	Pro-Lock High Strength Threadlocker	81792
2. Permabond International 480 South Dean Street Englewood, NJ 07631 (800) 370-9647 www.permabond.com	Cleaner & Primer	Perma-Lok Anaerobic Surface Conditioner	ASC10
	Adhesive	Perma-Lok Heavy Duty Bolt and Stud Locking Anaerobic Adhesive/Sealant	HH120
3. Hernon Manufacturing, Inc. 121 Tech Drive Sanford, FL 32771 (800) 527-0004 www.hernonmfg.com	Cleaner	Hernon Cleaner	EF-62
	Primer	Hernon Primer	EF-49
	Adhesive	Hernon Nuts N’ Bolts Anaerobic Adhesive	429
4. Saf-T-Lok 300 Eisenhower Lane North Lombard, IL 60148 (630) 495-2001 www.saftlok.com	Cleaner	Non Specified	-----
	Primer	Primer T	19166
	Adhesive	T77 High strength Anaerobic Adhesive	27741
5. Pacer 7001 Ardmore Avenue Fort Wayne, IN 46809 www.crosslink-tech.com	Cleaner	Non Specified	-----
	Primer	Primer	580-031
	Adhesive	ANL-77 Anaerobic Adhesive	560-073

All components used in a single threadlocking application shall be from one of the systems above and from the same threadlocking adhesive manufacturer.

Note: Refer to the Application Instructions.

For critical applications with regards to the breaking or prevailing torque values exercise caution and consult with a qualified engineer.

Also, exercise caution when using the Pacer brand product for stainless steel bolting applications.

Appendix C

Application Instructions for Caltrans-approved Anaerobic Threadlocking Systems:

The following application instructions shall be used for all Caltrans-approved anaerobic threadlocker systems previously listed. In the event of conflict between application instructions stated here and those of a manufacturer, the manufacturer's instructions shall take precedence.

The following 4-step application procedure shall be used for anaerobic threadlocker systems:

- 1) **Clean Threads;** Brush or spray the required cleaner/solvent onto both nut threads and stud threads at the desired final nut location to remove any lubricants; use only in a well-ventilated area. Scrub nut threads thoroughly using a small wire brush. Remove all traces of the dry lubricant from the internal threads of the nut. Allow the cleaner to completely evaporate before applying primer. Wait the required drying time as recommended by the threadlocker manufacturer.
- 2) **Prime Threads;** Apply primer liberally onto cleaned threads of both the stud (only in area where nut will be positioned) and the nut. Wait briefly until threads appear dry.
- 3) **Bond Threads;** Apply the anaerobic compound liberally onto the stud threads according to the instructions provided by the manufacturer. Coat only in the threaded area where the primer was applied (the final desired position to be occupied by the nut).
- 4) **Adjust Nut;** Thread the nut onto the rod until it contacts the threadlocking compound. Then install the nut by turning it in one full turn and then backing it off one-half turn to evenly distribute the adhesive. Continue this procedure until the nut is one complete turn past the desired final location. Place a small bead of threadlocker compound around the outboard side of the nut/rod interface. Then slowly back the nut up one complete turn to the final desired position. This procedure will ensure even distribution of the adhesive on the rod threads and seal any thread gap at the ends.

For nuts tightening against a positive stop, follow the above procedures until the positive stop or the final position is reached.

Basic Performance Requirements: To be acceptable for securing nuts approved threadlocker systems shall achieve a minimum breaking torque* of 61 N·m (45 lbs. ft.) when installed according to the above directions (or the manufacturer's recommended installation instructions) and cured for a minimum of 48 hours.

*Breaking torque is the initial torque required to cause the nut to begin to move on the threaded rod after the adhesive has fully cured. It is measured using a dial or digital (not click type) torque wrench, at the point the nut first begins to move relative to the threaded rod, while attempting to move/turn the nut in the direction that will unseat the nut.

Note: Refer to Table 1 for a listing of Caltrans-approved anaerobic threadlocking components.