LTPP Pavement Maintenance Materials: SPS-4 Supplemental Joint Seal Experiment, Final Report

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U.S. Department of Transportation
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Research, Development, and Technology
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LTPP

FOREWORD

During the conduct of the Strategic Highway Research Program (SHRP) on highway operations, rigid pavement, preventative maintenance treatments were placed on pavements throughout the United States. The placement and performance monitoring of these Specific Pavement Study (SPS)-4 projects have been conducted under the SHRP and Federal Highway Administration (FHWA) Long-Term Pavement Performance (LTPP) program. The information derived from this study will contribute greatly toward advancing the state of the practice of joint sealing and resealing of portland cement concrete (PCC) pavements.

This report provides information to pavement engineers and maintenance personnel on the results of the SPS-4 joint seal experiment. It presents the performance and cost data of various joint sealant materials, and procedures for sealing joints in PCC pavements.

This report will be of interest to anyone concerned with the maintenance and rehabilitation of PCC pavements.

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Director
Office of Infrastructure
Research and Development

NOTICE

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16. Abstract

The Strategic Highway Research Program (SHRP) Specific Pavement Studies (SPS)-4 preventive maintenance experiment was established to determine the benefits and cost-effectiveness of concrete maintenance activities, such as joint sealing and slab undersealing. Since 1989, several test sites have been constructed throughout the United States for this purpose.

A secondary investigation at some of these SPS-4 sites has focused on the long-term effectiveness of various joint seal treatments (i.e., combinations of sealant material and installation method) at preventing the infiltration of water into the pavement structure. Referred to as supplemental joint seal sites, a total of six such sites were constructed adjacent to SPS-4 test sites, and the performance of the various joint seal treatments have been monitored under the Federal Highway Administration (FHWA) Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites project.

This report documents the entire SPS-4 supplemental joint seal study, including the installation of 29 unique joint seal treatments, the laboratory testing of experimental sealant materials, and the multi-year performance monitoring of the various joint seal treatments. It also discusses the results of comprehensive statistical analyses conducted on sealant material performance.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celcius temperature	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

NOTE: Volumes greater than 1000 l shall be shown in m^3.

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celcius temperature	1.8C + 32	Fahrenheit temperature	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

(Revised September 1993)

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

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CHAPTER 1. INTRODUCTION

Objectives

Joint sealants are an integral part of any jointed plain concrete (JPC) or jointed reinforced concrete (JRC) pavement. Joint sealants provide protection for the pavement in two important manners. First, they reduce the infiltration of moisture at pavement joints—moisture that can lead to softening, pumping, and erosion of the base or subgrade near the joints, and ultimately to pavement distresses, such as corner breaks and faulting. Second, joint sealants protect the pavement by preventing incompressible materials from entering the joints. These incompressibles, such as small stones, enter the joints and inhibit thermal slab movement. As joints are filled with incompressible materials and slab expansion is restrained, the result is an increase in stresses in the pavement slabs, which can result in substantial joint spalling or possibly blow-ups. In essence, the success or failure of a jointed concrete pavement may often be attributed, in part, to the success or failure of the joint sealants.

The Strategic Highway Research Program (SHRP) acknowledged the important role of joint sealants in the performance of jointed concrete pavements and the need for research in this area. The SHRP Specific Pavement Studies (SPS)-4 experiment (Preventive Maintenance Effectiveness of Rigid Pavements), which involved the construction of several test sites nationwide, was primarily developed to answer questions about the effectiveness of joint sealing. Does sealing impart additional life to concrete pavements? Is sealing a cost-effective proposition?

Six particular SPS-4 sites, designated as supplemental joint seal sites, were constructed in four States in the SHRP western region to test the effectiveness of various joint seal materials and methods used in new and existing concrete pavements. Though initially monitored for performance under the SHRP Long-Term Pavement Performance (LTPP) program, the joint seals installed at these sites were subsequently evaluated under the Federal Highway Administration (FHWA) Long-Term Monitoring (LTM) of Pavement Maintenance Materials Test Sites project. The primary objectives of the SPS-4 supplemental joint seal experiment were as follows:

- Determine the sealant material–joint configuration combinations that perform best in newly constructed pavements.
- Determine the properties of sealants that relate best to long-term performance.

Scope

This report describes all aspects of the SPS-4 supplemental joint seal experiment, beginning with a discussion in chapter 1 of the materials and methods used, as well as descriptions of the selected test sites. Details of the installation of materials at each site are described in chapter 2, including site layout efforts, joint preparation and sealant placement procedures, productivity, and other observations. Included in chapter 3 are descriptions of the laboratory tests performed on some of the sealant materials and a discussion of the results of those tests. Summaries of the field performance data collected over the course of the experiment are provided in chapter 4 and an in-depth discussion of the analyses conducted on the performance data and the corresponding results is given in chapter 5. Lastly, chapter 6 presents an overall summary of the findings and recommendations of the study.

Project Overview

Between March 1991 and October 1992, a total of 106 test sections (including 14 unsealed sections) were installed at 5 different test sites located in Utah and Arizona. An additional 19 test sections (including 2 unsealed sections) were installed at a sixth test site in Colorado in November 1995, bringing the total number of test sections to 125. The six SPS-4 supplemental joint seal test sites, and the climatic zones in which they lie, are listed below and are illustrated in figure 1.

• U.S. 60—Mesa, Arizona	Dry-nonfreeze region
• U.S. 287—Campo, Colorado	Dry-freeze region
• I-80—Wells, Nevada	Dry-freeze region
• I-15—Tremonton, Utah	Dry-freeze region
• UT 154 (Bangerter Road)—Salt Lake City, Utah	Dry-freeze region
• U.S. 40—Heber City, Utah	Dry-freeze region

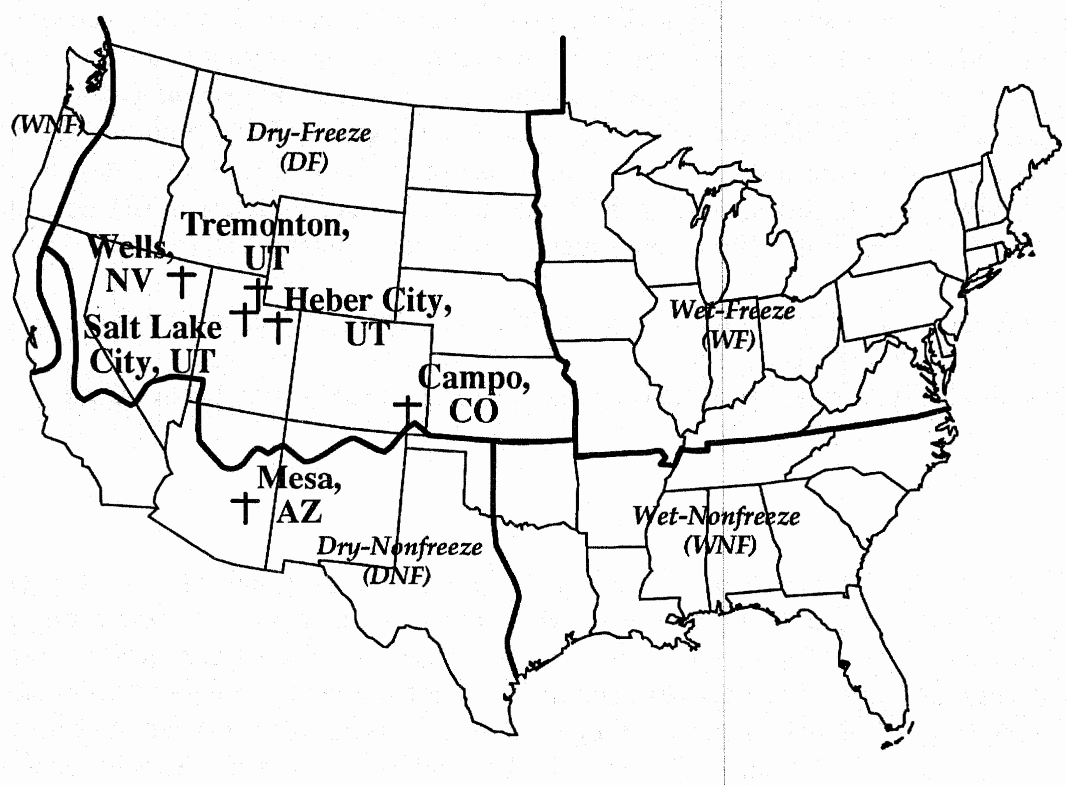

Figure 1. Locations of SPS-4 supplemental joint seal test sites.

With the exception of the Campo site, each site was located on moderate- to high-volume highway facilities consisting of four or six lanes in two directions. The Campo site was located on a two-lane highway having low traffic volume. Test sections at each site consisted of experimental seals placed in transverse contraction joints. However, at the Mesa and Wells sites, several test sections included experimental longitudinal joint seals in addition to the transverse contraction joint seals.

Sealant Materials

Overall, 21 different sealants were placed at the 6 test site locations. The majority of these sealants were silicone; however, several hot-applied sealants and preformed compression seals were also installed. Silicone sealants are defined as one-part polymer materials that, upon chemical curing, form a continuous silicone-oxygen-silicone network that is highly elastic and highly insensitive to environmental effects (e.g., temperature changes, ultraviolet light, hardening over time) (Smith et al., 1991). First-generation silicones were relatively viscous and had to be tooled into place within joints. These types of silicone are referred to as standard, non-sag, or non-self-leveling silicones. In recent years, more fluid-like formulations of silicone were developed that do not require tooling into place. These types of silicones are referred to as self-leveling silicones. The silicone sealants used in the SPS-4 supplemental joint seal test sections are as follows:

- Crafco 902 — Non-self-leveling
- Crafco RoadSaver (RS) 903-SL — Self-leveling
- Dow Corning 888 — Non-self-leveling
- Dow Corning 888-SL — Self-leveling
- Dow Corning 890-SL — Self-leveling
- Mobay Baysilone 960 — Non-self-leveling
- Mobay Baysilone 960-SL — Self-leveling

Hot-applied sealants are asphalt- or tar-based sealants that become soft upon heating and harden upon cooling, usually without a change in chemical composition (Smith et al., 1991). Most hot-applied sealants are asphalt-based (derived from the distillation of crude oil) and include rubber-, polymer-, or fiber-modifiers to impart desirable elastic and tensile strength properties. Tar-based sealants (derived from the destructive distillation of coal) are largely resistant to fuel spillage and are usually modified with rubbers or polymers. In this experiment, four hot-applied sealants were used in Arizona and the three Utah locations. These sealants are as follows:

- Crafco RS 221 — ASTM D 3405
- Crafco SuperSeal (SS) 444 — ASTM D 3406
- Koch 9005 — ASTM D 3405
- Koch 9012 — ASTM D 3406

Each test site contained at least one test section with neoprene compression seals. These seals are premolded synthetic materials that are inserted (often with the aid of a lubricant/adhesive) into joints in a state of compression. They are designed to maintain contact pressure with the joint faces and therefore are not subject to adhesion failures. The neoprene materials used in the SPS-4 supplemental joint seal experiment are as follows:

- D.S. Brown E-437H
- D.S. Brown V-687
- D.S. Brown V-812
- Kold Seal Neo Loop
- Esco PV 687
- Watson Bowman 687
- Watson Bowman 812

In addition to the above sealant products, a self-leveling polysulfide sealant (Koch 9050-SL), a polyethylene sealant (product name unknown), and a proprietary sealant (named after Mike Roshek of the Utah Department of Transportation [DOT]) were installed.

<u>Joint Preparation Methods</u>

Because of the varying interests and practices of each participating State highway, the sealant materials were installed using many different joint preparation methods. For instance, seven different combinations of joint configuration/construction were used throughout the experiment, as described below and illustrated in figure 2.

- Configuration A—Formed using a standard riding saw, the joint width of this configuration was nominally 3 mm and the depth was nominally one-third or one-fourth the slab thickness. This configuration was used only with some of the silicone sealants.

- Configuration B—The nominal joint width of 6 mm for this configuration was also formed using a standard riding saw. Both silicone and neoprene compression seals were placed in this configuration. For silicone sealants, the minimum depth was 38 mm to accommodate the backer rod, sealant, and sealant recessment. Less depth was needed for neoprene compression seals; however, a depth of 38 mm was still typically used.

- Configurations C and G—Both of these 9-mm-wide by 38-mm-deep configurations were created using a standard riding saw. However, to investigate the possible reduction of sliver spalls at one site, configuration G included beveling of the upper 3 mm of each joint edge at a 45-degree angle. Only 10 joints (sealed with a non-self-leveling silicone) were fashioned in this configuration, as it was determined that the sawing/beveling process caused excessive raveling and resulted in aesthetically displeasing joint edges. All sealant types, except polyethylene, were installed in configuration C.

- Configuration D—In this configuration, nominal joint dimensions of 13 mm wide and 41 mm deep were created using a standard riding saw. Only one sealant type, a neoprene compression seal, was installed in this joint configuration.

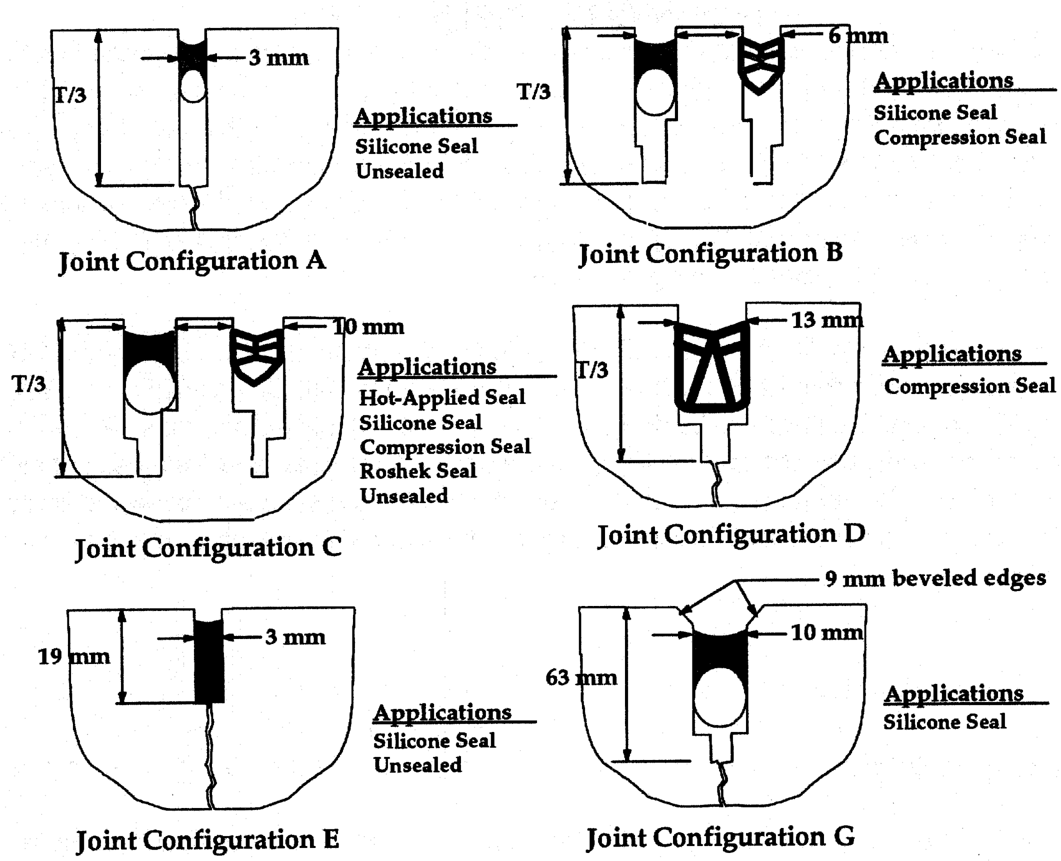

Figure 2. Joint configurations for SPS-4 supplemental joint seal test sites.

- Configuration E—The joint width of this configuration was the same as that of configuration A (nominally 3 mm deep). However, the joints were created using the Soff-Cut sawing method, whereby joints are sawed shallower (typically 19 mm) and much sooner than conventional sawcutting.

- Configuration F—The dimensions of this configuration were not known, since the test site in which it was used (Wells) was located on a pavement originally constructed and sealed with polyethylene long before the pavement was made into an SPS-4 test site. This configuration was designated as an "undisturbed" joint configuration.

Another aspect of joint preparation was the cleaning method used to ensure clean joint sidewalls for proper adherence by the experimental seals. Though the same cleaning method was essentially used for each sealant at a given site, the methods varied somewhat from site to site. For instance, at the Mesa site, each joint was sandblasted, waterblasted, and airblasted, whereas at the Wells site, each joint was sandblasted and airblasted. At the Tremonton site, each joint was waterblasted and airblasted, whereas most joints at the Salt Lake City site were only airblasted. Though the performance analyses described later in this report are confined to individual test sites, this information about joint cleaning methods was deemed noteworthy, so as to prevent the development of incorrect, broad-based conclusions about seal performance.

The use of 21 different sealant materials and 7 different joint configurations resulted in a total of 29 distinct joint seal treatment types (i.e., material–configuration combinations). Table 1 summarizes the joint seal treatment types applied at each test site and shows the number of test sections of each treatment type. It can be seen that several of the treatments were unique to only one site. However, overlooking the different joint cleaning methods used at the various sites, it can also be seen that some treatment types (e.g., Crafco 903-SL in configuration C, Dow 888-SL in configuration C) were used at multiple test sites.

The experimental layout varied greatly from site to site. Each test site contained from 17 to 24 test sections. Either two or four of these sections were designated specifically as SHRP test sections; the remaining sections were designated as State supplemental sections. With the exception of the Wells test sections, which contained only 15 transverse joints, each section contained between 25 and 48 transverse joints in which the experimental joint seals were placed. Appendix A provides the physical layout of the various material–configuration combinations at each test site.

Test Site Characteristics

U.S. 60, Mesa, Arizona

This test site is located in the dry-nonfreeze climatic region of the United States along a 3.5-km stretch of highway more commonly known as Superstition Freeway. The test sections are located in the eastbound travel lanes, and are bounded by Power Road and Ellsworth Road, as illustrated in figure 3. The highway consists of six lanes in two directions, with each lane approximately 3.7 m wide. The pavement was constructed in February 1991 and consists of a 330-mm-thick JPC pavement, placed on 102 mm of compacted aggregate base on a compacted subgrade. The joint spacing is staggered at intervals of 4.0, 4.6, 5.2, and 4.6 m. Experimental joint seals were installed shortly after pavement completion in February 1991. The pavement was designed for 2.9 million 80-kN equivalent single-axle loads (ESALs) and a 20-year design life. Average annual precipitation at this site is about 178 mm, and the average monthly temperatures range from about 10 to 33°C (U.S. Dept. of Commerce, 1983).

U.S. 287, Campo, Colorado

This test site is located in the northbound lane of U.S. 287 in Baca County, 4.8 km south of Campo, in southeastern Colorado. The specific location of the test site is shown in figure 4. The test site is approximately 2.1 km long, and the two-lane highway on which it sits has 3.7-m-lanes and 3.0-m-wide paved shoulders. Constructed in October and November of 1995, the pavement was designed to carry 10 million 80-kN ESALs for its 30-year design period. The pavement structure consists of 254 mm of portland cement concrete (PCC) placed on 610 mm of unbound

Table 1. Summary of materials and procedures used for joint seal installation.

Sealant Material	Joint Configuration/ Construction	Number of Test Sections Installed at Test Site					
		Mesa, AZ (U.S. 60)	Campo, CO (U.S. 287)	Wells, NV (I-80)	Tremonton, UT (I-15)	Salt Lake City, UT (UT 154)	Heber City, UT (U.S. 40)
Crafco RS 221	C	2				2	
Crafco SS 444	C	2					
Crafco 902	A		2				
	B		2				
	C		3	2			
	G		2				
Crafco 903-SL	A		2				
	B		2				
	C	2	2	2			
Dow 888	C	2		3		2	2
Dow 888-SL	C	2		2	2	2	2
Dow 890-SL	A	2			2	2	2
	B	2					
	C	2		2			
	E				1	2	2
DS Brown E-437H	B		1			2	2
DS Brown V-687	C	2	1			2	2
DS Brown V-812	D			2			
Koch 9005	C				2		2
Koch 9012	C				2	2	2
Koch 9050-SL	C					2	2
Kold Seal Neo Loop	B				2		
Mobay 960	C			2	4		
Mobay 960-SL	C	2					
Roshek	C				1		
Esco PV 687	C				2		
Watson Bowman 687	C	1					
Watson Bowman 812	C	1					
Unsealed	A	2	2		2	2	2
	C			1			
	E				1	2	2
Polyethylene	F			1			
Total Treatment Types (excl. unsealed)		12	9	8	9	9	9
Total Test Sections		24	19	17	21	22	22

Joint Configuration/Construction

A. Standard saw, 3-mm joint width.
B. Standard saw, 6-mm joint width.
C. Standard saw, 9-mm joint width.
D. Standard saw, 13-mm joint width.
E. Soff-Cut saw, 3-mm joint width.
F. Undisturbed.
G. Standard saw, 9-mm beveled joint.

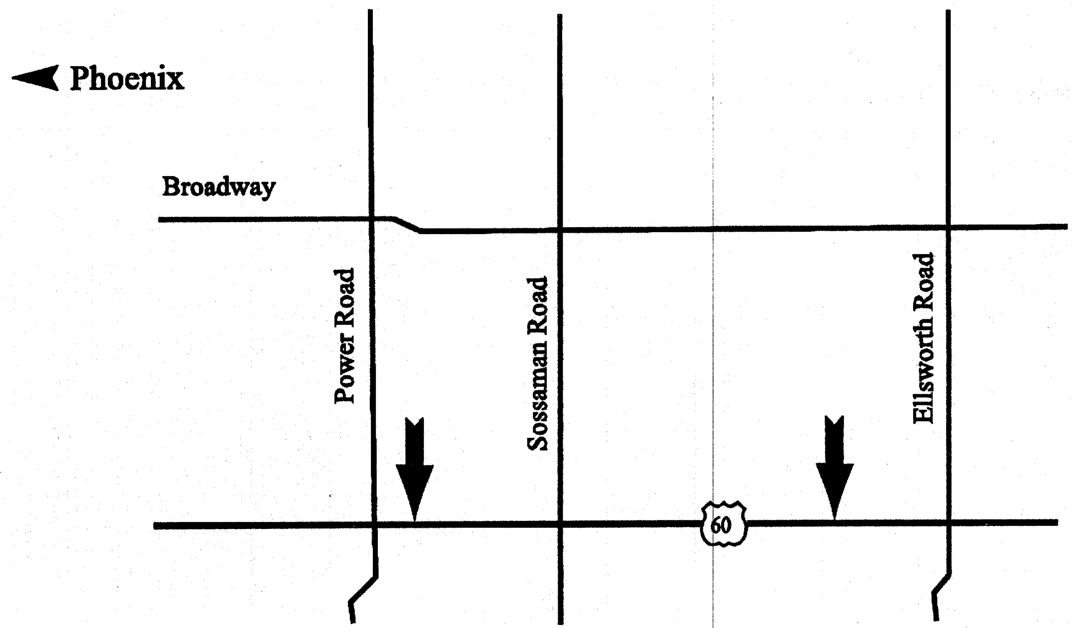

Figure 3. Mesa, Arizona SPS-4 supplemental joint seal test site location.

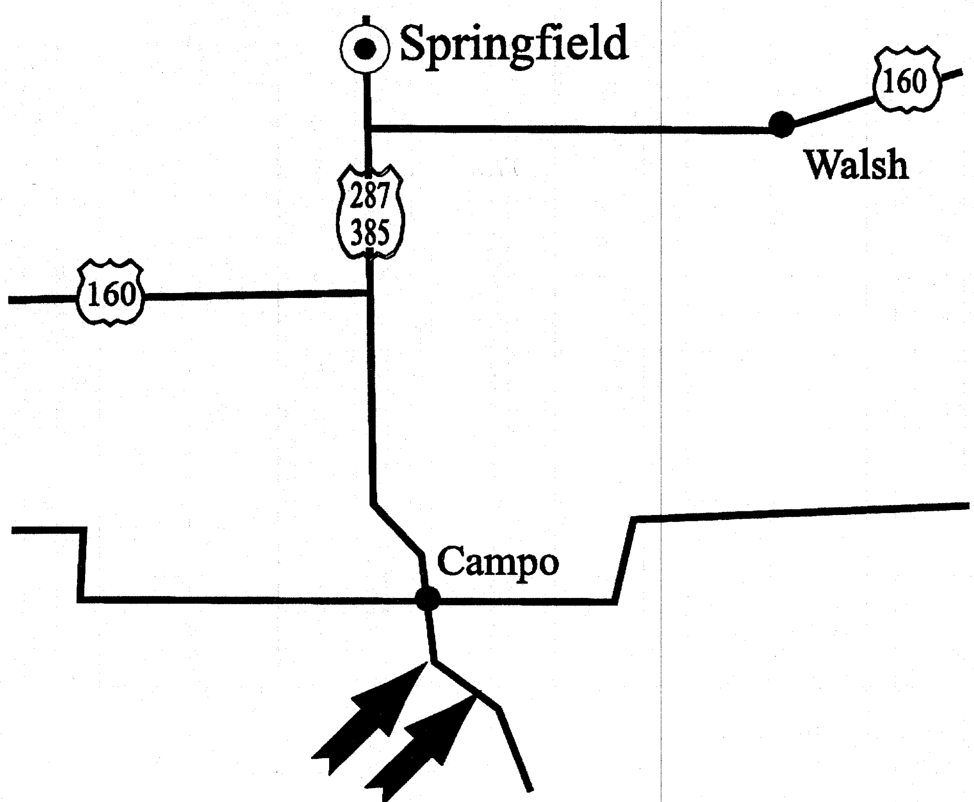

Figure 4. Campo, Colorado SPS-4 supplemental joint seal test site location.

R-70 select soil (compacted to 95 percent of maximum dry density) and a sandy, drainable subgrade. The transverse joints are doweled and unskewed, with an even joint spacing of 4.6 m. Experimental seals were installed shortly after completion of paving in November 1995. The average annual precipitation at this dry-freeze site is about 377 mm, and the average monthly temperatures range from about 0 to 25°C (U.S. Dept. of Commerce, 1983).

<u>I-80, Wells, Nevada</u>

This dry-freeze test site is located in Elko County, west of Wells, in the westbound and eastbound driving lanes of I-80 in northeastern Nevada. Figure 5 shows the specific location of the test site. Though the pavement was originally built in March 1980, the experimental joint seals were installed in August 1991. The pavement was constructed using 246 mm of JPC placed on a 152-mm cement-treated base, 112 mm of aggregate subbase, and a silty-sand subgrade. The transverse joints were skewed, doweled, and spaced in a random pattern of 4.3, 4.0, 5.8, and 5.8 m. Sealant was placed in the joints at the time of original construction, but was removed as part of the 1991 experimental seal installation. The length of the test site is approximately 1.0 km. The interstate on which it lies consists of two 3.7-m-wide lanes in each direction, with 3.0-m- and 1.2-m-wide PCC outside and inside shoulders, respectively. The average annual precipitation at this site is about 305 mm, and the average monthly temperature ranges from about -5 to 22°C (U.S. Dept. of Commerce, 1983).

<u>I-15, Tremonton, Utah</u>

Located approximately 8 km north of the Riverside/Logan exit, this test site is situated in the northbound and southbound driving lanes of the four-lane I-15 in north central Utah. Figure 6 shows the specific location of this dry-freeze site. The pavement was constructed in October 1990 with 254 mm of JPC placed on a 102-mm lean concrete base and a 102-mm crushed gravel subbase. Additional support consisted of 457 mm of well-graded gravel with sand placed on a subgrade of well-graded gravel with cobbles. Transverse joints were spaced at repeated intervals of 3.0, 4.6, 3.4, and 4.3 m, and were made skewed and undoweled. The experimental joint seals were installed a few weeks after pavement construction. The travel lanes of the facility are 3.7 m wide, and the PCC outside and inside shoulders are 2.4 m and 0.9 m, respectively. The average annual precipitation at the Tremonton site is approximately 406 mm, and the average monthly temperatures range from about -7 to 23°C (U.S. Dept. of Commerce, 1983).

<u>UT 154, Salt Lake City, Utah</u>

This dry-freeze test site is located in the northbound and southbound lanes of Utah Route 154 (Bangerter Road) in the southern part of Salt Lake City. Specifically, it is located between 3500 South Street and 4100 South Street, as illustrated in figure 7. The test site pavement was constructed in the fall of 1991 and spring of 1992. Shortly after construction, the experimental joint sealants were installed. The pavement was constructed with 254 mm of JPC placed on a 102-mm lean concrete base, 102 mm of crushed gravel subbase, and 305 mm of poorly graded

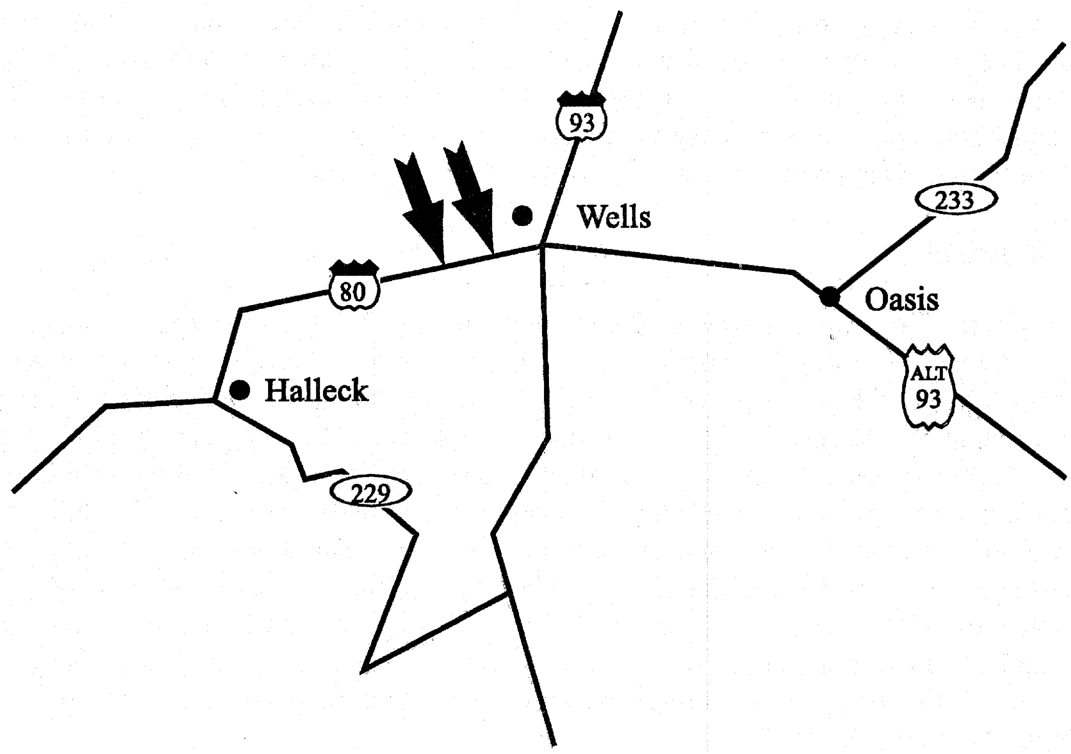

Figure 5. Wells, Nevada SPS-4 supplemental joint seal test site location.

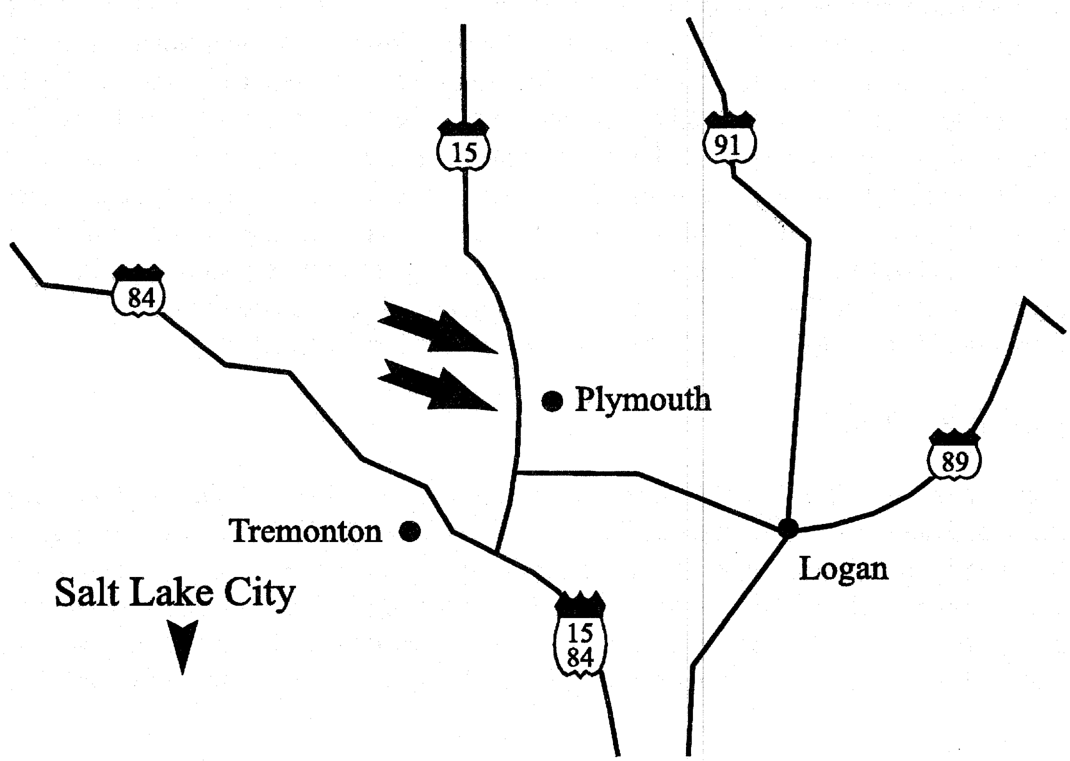

Figure 6. Tremonton, Utah SPS-4 supplemental joint seal test site location.

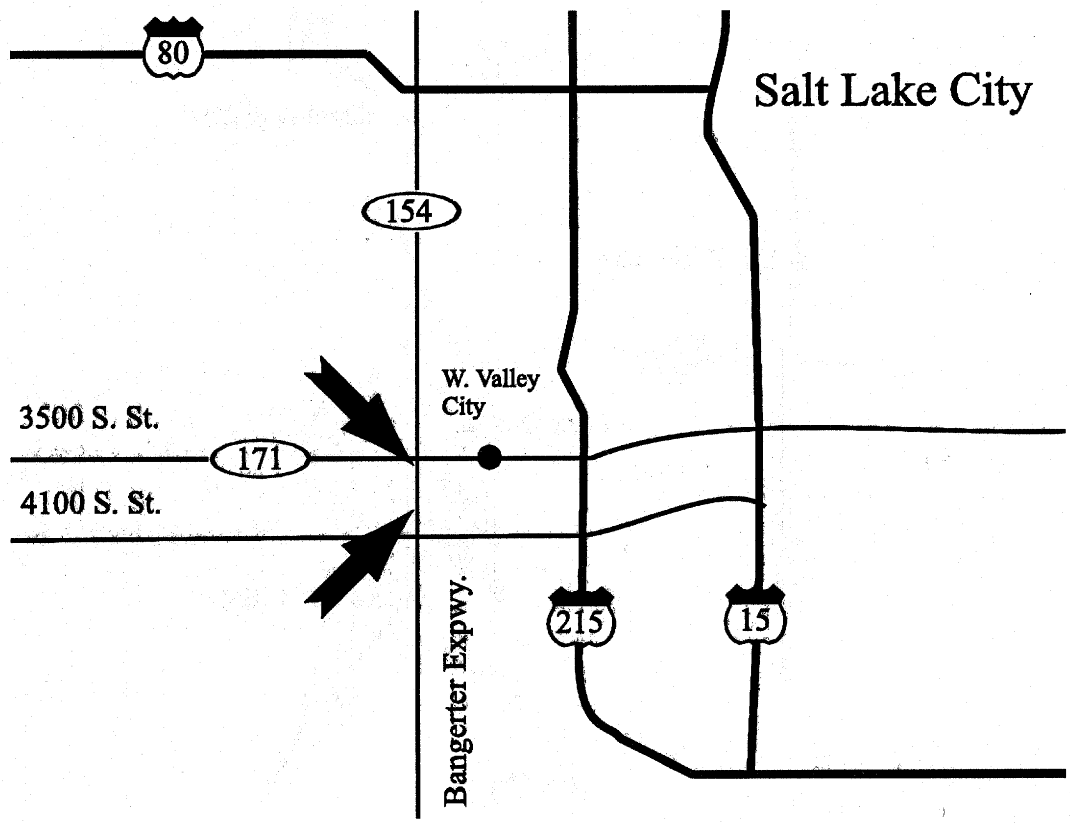

Figure 7. Salt Lake City, Utah SPS-4 supplemental joint seal test site location.

gravel. A 305-mm geo-grid layer of clean, free-draining gravel and filter fabric was placed beneath the poorly graded gravel, and the entire structure rests on a sandy clay subgrade. Transverse joints were constructed at staggered intervals of 3.0, 4.6, 3.4, and 4.3 m. These joints were skewed, but undoweled. The highway on which the test site lies consists of six lanes (in two directions), with each lane approximately 3.7 m wide. The curb and gutter flank the outside lanes, whereas a 3.7-m-wide PCC shoulder adjoins the inside lanes. The average annual precipitation of this test site is approximately 610 mm, and the average monthly temperatures range from about -3 to 24°C (U.S. Dept. of Commerce, 1983).

U.S. 40, Heber City, Utah

This test site is located in the eastbound and westbound lanes of U.S. 40, approximately 50 km southeast of Salt Lake City, in north central Utah. As seen in figure 8, the site is located between mileposts 5 and 6.5 on U.S. 40. Though this four-lane highway extends north and south at the location of the test site, it is technically an east-west route. The pavement was constructed in September 1991, and the experimental joint sealants were installed shortly thereafter. The travel lanes were constructed with PCC to a thickness of 254 mm. The pavement base in the westbound lanes consisted of an unknown thickness of asphalt concrete (AC), whereas 102 mm of lean concrete were used for the base in the eastbound lanes. The subbase in both directions

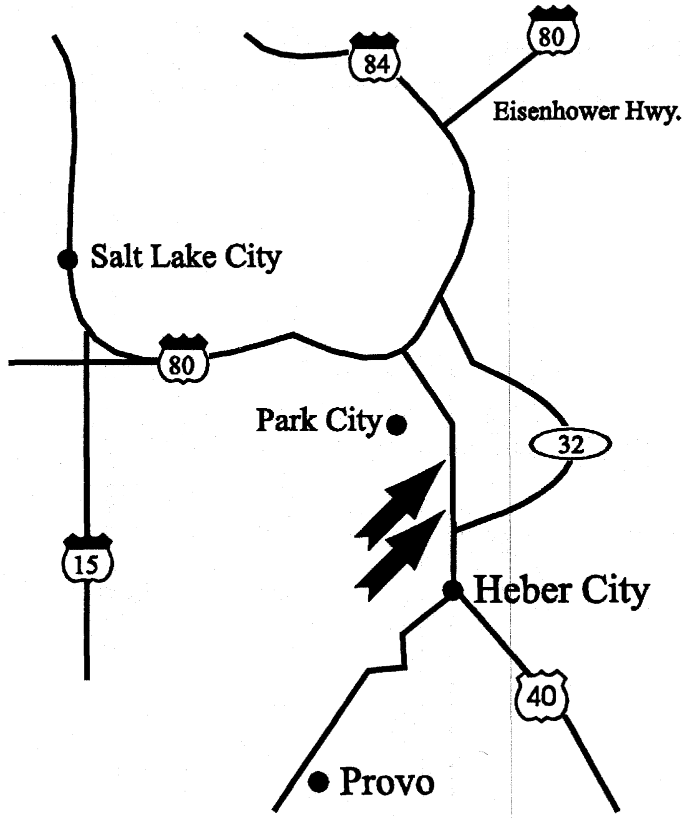

Figure 8. Heber City, Utah SPS-4 supplemental joint seal test site location.

consists of 102 mm of crushed gravel placed on 457 mm of silty, sandy gravel and a poorly graded gravel subgrade. Skewed, undoweled transverse joints were constructed at staggered intervals of 3.0, 4.6, 3.4, and 4.3 m. The pavement consists of two 3.7-m-wide lanes in each direction, with 2.4-m- and 1.2-m-wide PCC outside and inside shoulders, respectively. Average annual precipitation at the Heber City test site is approximately 610 mm, and the average monthly temperatures range from -6 to 22°C (U.S. Dept. of Commerce, 1983).

CHAPTER 2. TEST SITE INSTALLATIONS

As discussed in chapter 1, five of the six SPS-4 supplemental joint seal test sites involved the installation of experimental sealants in newly constructed PCC pavements, thereby classifying them as joint seal sites. Since the pavement at the Wells site was originally built in 1980 (joints were initially sealed at that time), but the experimental sealants were not installed until 1991, this site is classified as a joint reseal site.

In the case of the five sites containing new seals, the pavement construction contracts were originally written to include the experimental joint seal installation work or the necessary change orders were developed to allow the experimental installations to occur. At each of these five sites, the experimental installations followed closely behind the pavement construction process (usually within a few weeks), as indicated in table 2. At all six test sites, the sealant installations were performed by contractors selected by the sponsoring State highway agency (SHA). These contractors are also listed in table 2.

Test Site Planning, Coordination, and Layouts

As primary beneficiaries of the SPS-4 test results, each sponsoring State highway agency had control over the design and layout of the test sites installed in their State. The selections of material products and procedures, along with the planning of joint seal treatment locations and boundaries, were generally made by key researchers, engineers, and administrators within the sponsoring DOTs.

Table 2. Test site construction and experimental joint seal installation information.

Test Site	Pavement Construction and Primary Sawing Dates	Secondary Sawing and Experimental Sealant Installation Dates	Sponsoring Highway Agency	Experimental Sealing Contractor
U.S. 60—Mesa, AZ	2/13/91 - 2/15/91	3/18/91 - 3/31/91	Arizona DOT	Multiple Concrete Enterprises, Inc.
U.S. 287—Campo, CO	10/24/95 - 11/15/95	11/15/95 - 11/19/95	Colorado DOT	Castle Rock Construction, Inc.
I-80—Wells, NV	3/80	8/14/91 - 8/22/91	Nevada DOT	Diversified Concrete Cutters, Inc.
I-15—Tremonton, UT	10/9/92 - 10/23/92	10/23/92 - 10/26/92	Utah DOT	Concrete Sawing and Sealing, Inc.
UT 154—Salt Lake City, UT	Fall 1991 - Spring 1992	5/19/92 - 5/27/92 (SB) 6/29/92 - 8/14/92 (NB)	Utah DOT	A-Core, Inc.
U.S. 40—Heber City, UT	6/26/91 - 7/8/91 (EB) 9/16/91 - 9/23/91 (WB)	7/8/91 - 7/11/91 (EB) 9/23/91 - 10/1/91 (WB)	Utah DOT	Multiple Concrete Enterprises, Inc.

The proposed experimental joint seal treatments and testing sequences for a given site were usually detailed in an experimental plan. Some changes were made to the original experimental plans developed by each sponsoring agency, as a result of problems incurred with the installation of the materials (e.g., running out of sealant, joint preparation problems, sealant preparation problems). These changes were documented in each of the six SPS-4 supplemental joint seal construction reports (Meier, 1992; Wienrank and Evans, 1995a, 1995b, 1995c, 1995d; Ambroz and Evans, 1996).

Figures 9 through 14 show the final layouts of each test site. As can be seen in these figures, each test section was assigned a test section number, corresponding to its location in the field testing sequence, and a six-digit SHRP identification (ID) number, indicating the State in which the test section is located and the sealant material and procedure used in the section. In most cases, two replicate test sections of each material–procedure combination were established, either in opposite directions or in the same direction, but spaced apart from each other.

The size of test sections varied, both in terms of length and number of transverse joints. Sections ranged between 56 and 183 m long and were comprised of between 15 and 48 transverse joints. At the Arizona and Nevada sites, the same sealant placed in the transverse joints of a given test section was typically used to seal the longitudinal joints within that section. At the other four test sites, one sealant was typically used throughout the entire site to seal the longitudinal joints.

All test sections were marked according to standard SHRP-LTPP guidelines. Permanent signing was erected to indicate the boundaries of the entire test site, as well as the beginning and end of each individual test section. Each test section was also marked with two white paint stripes extending across the test lane. These stripes were located at the beginning and end of each section. In most cases, the six-digit SHRP ID number was painted at the beginning of the test section, near the outside shoulder.

Installation Processes

In general, the experimental sealant installation process at each site consisted of five steps, following the completion of concrete paving operations. These steps were as follows:

1. Primary/initial joint sawing.
2. Secondary/reservoir joint sawing.
3. Joint cleaning.
4. Backer material placement.
5. Sealant application.

Since the Wells site was installed on an in-service concrete pavement with initially sealed joints, the first step in this process was not needed and the second step served the combined purpose of removing old sealant and widening the joint to the specified test width. Additionally, the fourth step was not required for use with neoprene compression seals, nor was it used in the 3-mm Soff-Cut joints that were sealed with Dow 890-SL silicone at the Salt Lake City and Heber City sites.

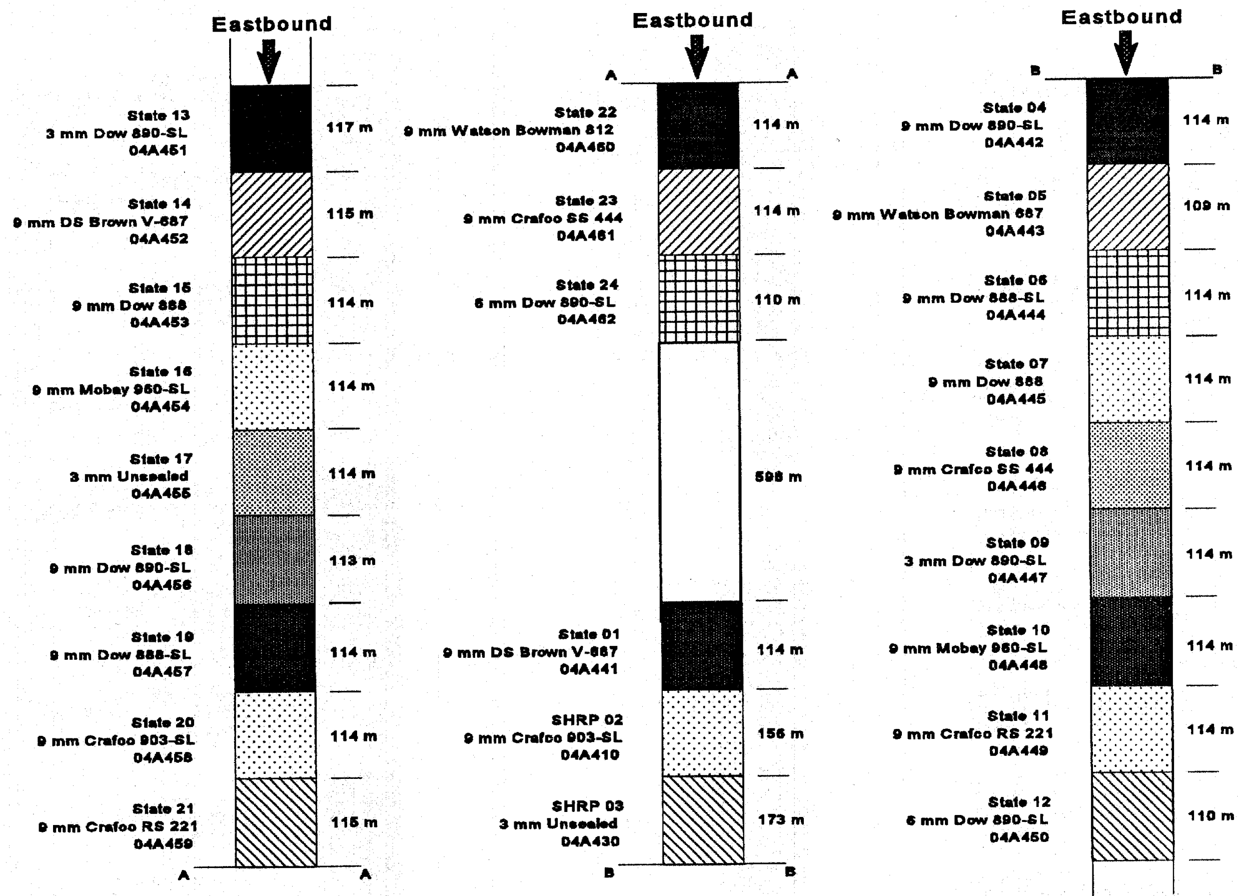

Figure 9. Mesa, Arizona test site layout.

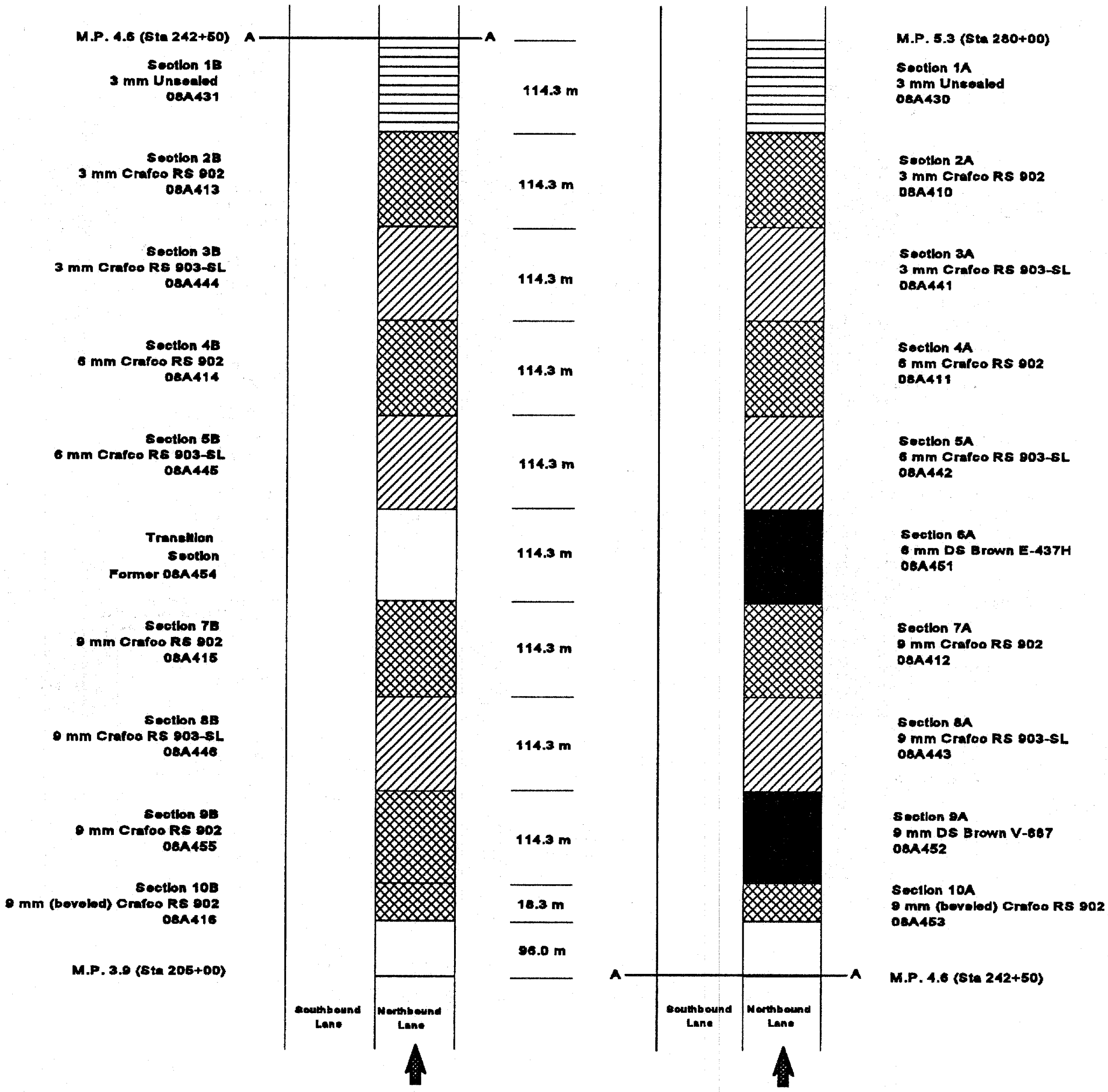

Figure 10. Campo, Colorado test site layout.

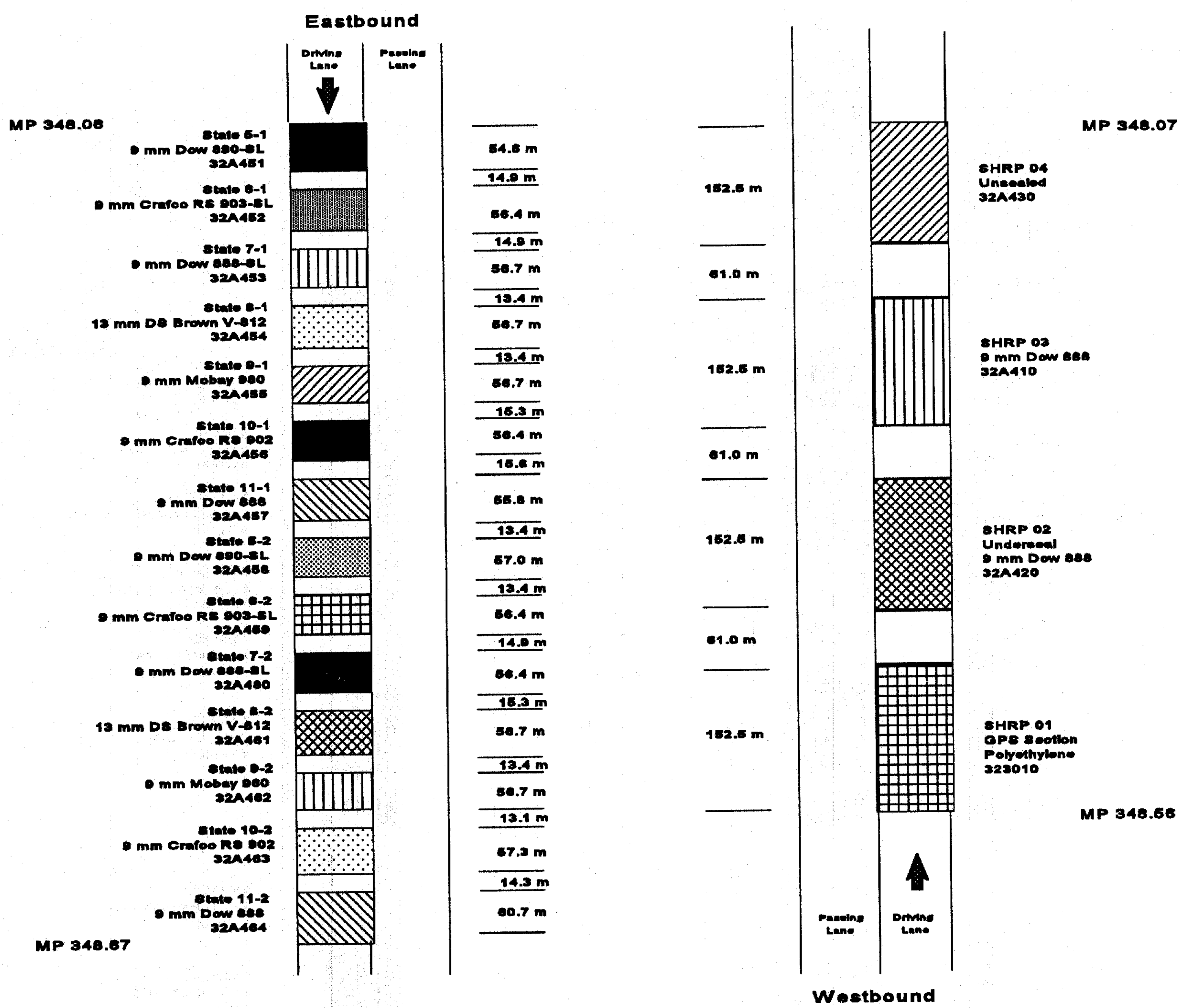

Figure 11. Wells, Nevada test site layout.

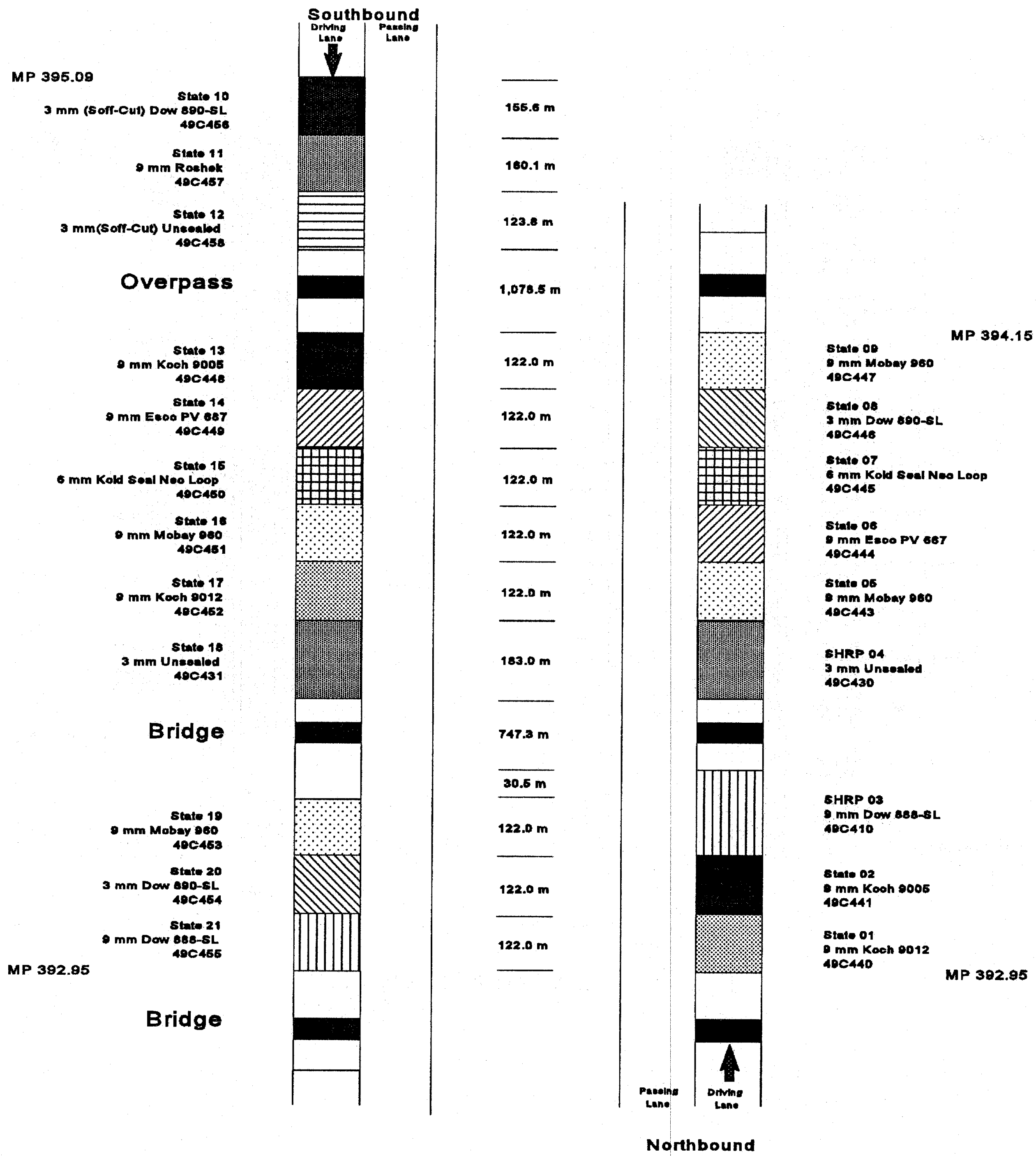

Figure 12. Tremonton, Utah test site layout.

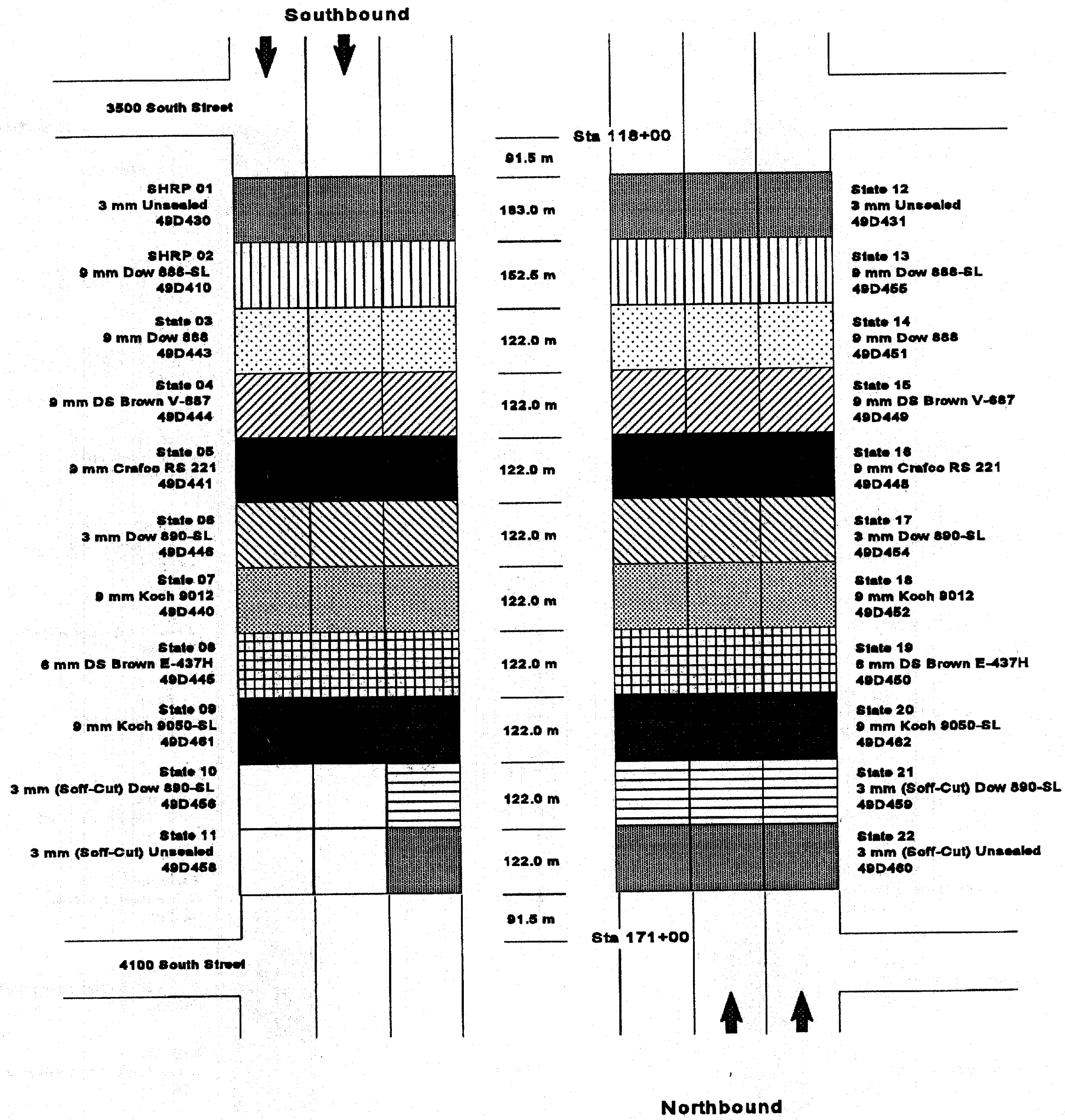

Figure 13. Salt Lake City, Utah test site layout.

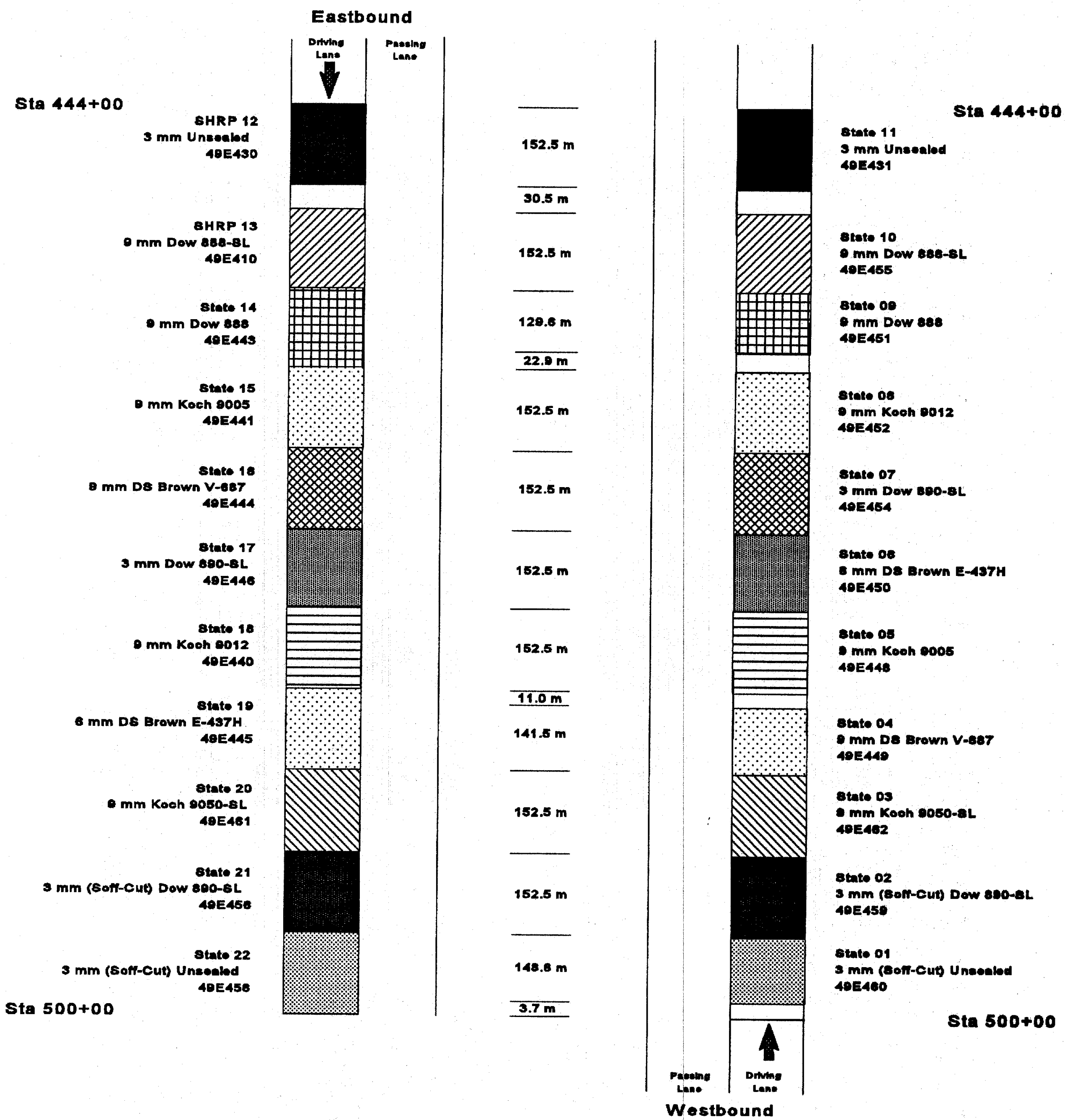

Figure 14. Heber City, Utah test site layout.

Primary Joint Sawing

In most cases, primary joint sawing was accomplished using a water-cooled riding saw with a 305- to 356-mm-diameter single-saw blade. The width of the primary sawcut was approximately 3 mm, while the depth was typically maintained to either one-third or one-fourth the thickness of the concrete slabs. This step was performed as soon as the concrete had cured to the point that extensive raveling would not occur. Figure 15 illustrates the primary sawcutting operation, as performed at the Wells site.

Primary joint sawing using the Soff-Cut procedure differed slightly from conventional means. Because the Soff-Cut pavement saw is lighter than conventional saws, sawing operations can be performed sooner after the paving process (essentially as soon as the pavement can support the weight of the saw) and consequently require a shallower cutting depth. As a result of the shallower cut, the productivity of the operation is increased. The Soff-Cut joints created at the Tremonton, Salt Lake City, and Heber City sites were typically between 19 and 25 mm deep. These cuts were substantially shallower than the 85-mm-deep cuts created using conventional saws.

Secondary Joint Sawing

Several experimental joints required a secondary sawcut in order to produce the specified sealant shape factor. In most cases, these cuts were made with one pass of a riding saw having water-cooled, 305- or 356-mm-diameter blades. For wider cuts, double and triple blades were

Figure 15. Primary joint sawing operation at Wells, Nevada test site.

used. Secondary cuts were not as deep as primary cuts, and they varied according to the sealant and configuration used. Some spalling and raveling of pavement joint edges were observed during the secondary sawcutting operations, particularly in the Crafco RS 902 beveled-joint sections installed at the Campo site.

Joint Cleaning

Different methods of joint cleaning were used at each test site. The methods involved one or a combination of the following four techniques:

- High-pressure airblasting.
- Waterwashing.
- High-pressure waterblasting.
- Sandblasting.

Joints that were to be left unsealed were not cleaned at all. Table 3 lists, in sequence, the techniques used to clean the joints at each site. Figure 16 shows the sandblasting of a joint located at the Wells test site.

Table 3. Methods used for cleaning each site.

Test Site	Step 1	Step 2	Step 3	Step 4	Step 5	Step 6
Mesa, Arizona	827-kPa Airblast	Dry saw	Sandblast (2 passes)	Airblast	Waterblast	Airblast
Campo, Colorado	Waterwash	Air dry (30 min)	621-kPa Sandblast	621-kPa Airblast		
Wells, Nevada	Sandblast (2 passes)	862-kPa Airblast				
Tremonton, Utah	6,895-kPa Waterblast	Waterwash	Air dry	690-kPa Airblast		
Salt Lake City, Utah	19,306-kPa Waterblast (2 compression seal sections only)	586- to 1,034-kPa Airblast				
Heber City, Utah	552-kPa Waterblast (WB sections) 6,895-kPa Waterblast (EB sections)	690-kPa Airblast (WB sections) 3,448-kPa Airblast (EB sections)				

Figure 16. Sandblasting operation at Wells, Nevada test site.

Backer Material Placement

Backer rods were used to prevent field-molded sealants from flowing down into the joints and to provide a more uniform sealant depth and shape factor. Typically, heat-resistant foam backer rod materials were used in conjunction with the hot-applied sealants, whereas non-heat-resistant materials were used with the silicone and polysulfide sealants. For 9-mm-wide joints, 13-mm-diameter backer rods were used; for 6-mm-wide joints, 8- and 9-mm-diameter rods were used; and for 3-mm-wide joints, 6-mm-diameter rods were used. All backer rods were installed after the final joint cleaning and just prior to the actual application of the sealant. Figure 17 shows backer rod being installed with a backer rod tool at the Campo test site. The backer rod tool facilitates placement and provides uniform depth of insertion.

Sealant Application

In general, experimental joints were sealed within 3 to 4 hours after final cleaning. However, joints in some of the test sections at Salt Lake City and Tremonton were not sealed until 24 to 48 hours after cleaning. Visual observations of joint cleanliness and dryness by SHRP contractor field representatives indicated that joints at the Wells and Tremonton sites were dry and clean, whereas joints at the Campo, Heber City, and Salt Lake City sites were mostly dry, to dry and mostly clean, to clean. Visual observations of joint cleanliness and dryness at the Mesa site were not reported.

Figure 17. Backer rod placement at Campo, Colorado test site.

Hot-Applied Sealants

Experimental hot-applied sealants were heated in asphalt kettles to temperatures ranging from 123 to 210°C. To prevent burning of sealant material and to promote uniform heating, each hot-applied sealant was mechanically stirred with agitator paddles located within the heating vats of the asphalt kettles. Once the recommended melting temperature of a particular sealant was reached, the sealant was pumped through a hose-and-wand unit into the bottom of the prepared joints, as illustrated in figure 18.

Overall, very little difficulty was experienced with the installation of hot-applied sealants. The only notable problems included extended heating of Crafco SS 444 at the Mesa site (Meier et al., 1992), some difficulties maintaining proper temperature of Koch 9012 at the Tremonton site (Wienrank and Evans, 1995b), and contamination of Koch 9012 at the Salt Lake City site (Wienrank and Evans, 1995c).

Silicone Sealants

Experimental silicone sealants were placed into joints under pressure using a joint sealant pump (typically 208 L) mounted on either a flatbed truck or a trailer (figure 19). Application pressures ranged from 240 to 690 kPa. Regular, or non-self-leveling, silicones were tooled to ensure good contact with joint surfaces, to control sealant depth, and to produce the required recessment below the pavement surface. At most sites, tooling was accomplished using a piece of flexible tubing attached to the end of a broom handle.

Figure 18. Hot-applied sealant installation at Heber City, Utah test site.

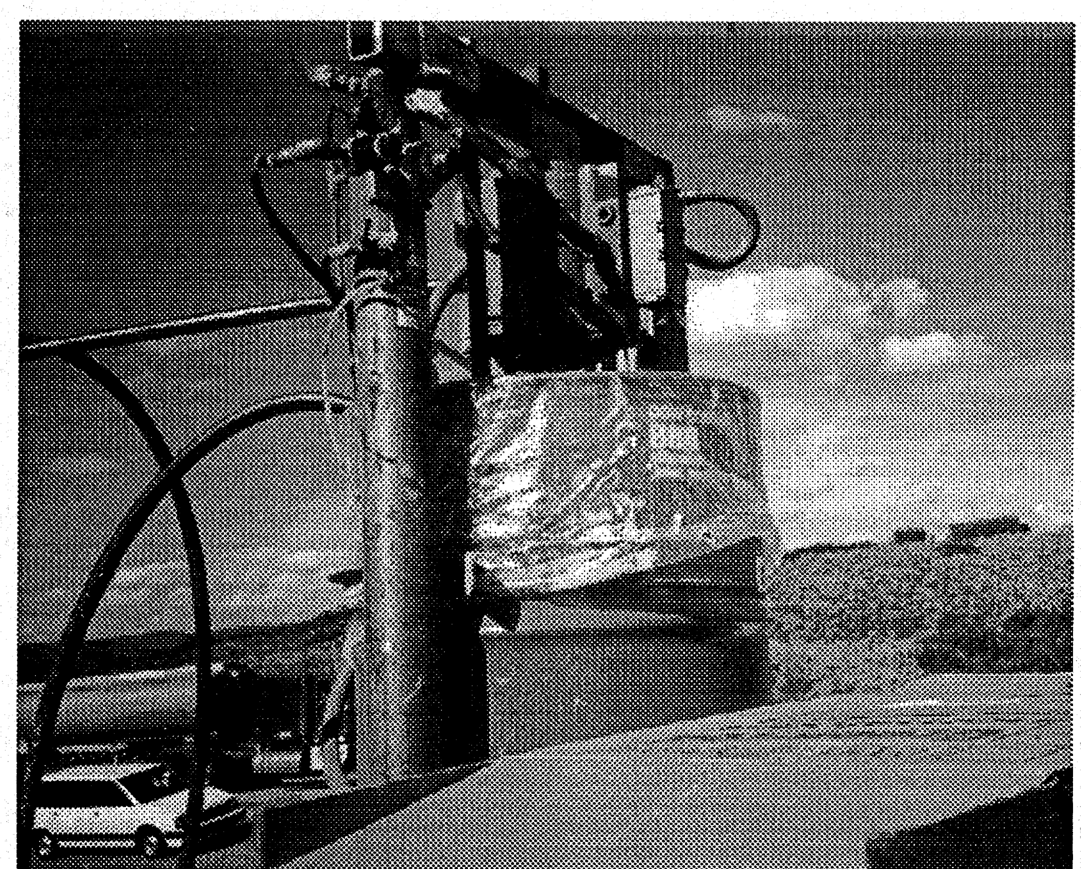

Figure 19. Silicone sealant pumping apparatus used at Heber City, Utah test site.

The only reported installation problem associated with the non-self-leveling silicones was the buildup of material along the tops of joint walls at the Campo site. It was determined that the tool used to form a concave surface in the silicones was not sufficiently wide or flexible enough to force the sealant against both sides of the joint.

Because of their fluid-like natures, self-leveling silicones required no tooling after application. These sealants were simply dispensed into the joint bottom and allowed to level under gravity to the specified recessment below the pavement surface.

A few difficulties were encountered with the self-leveling silicones. At the Heber City and Salt Lake City sites, sealing crews had trouble applying sealant into 3-mm-wide joints. To overcome this problem, crews ground down the nozzle located on the end of the application wand so that it would fit into the narrow joints. A similar problem encountered at the Mesa site was resolved by using a smaller modified nozzle taken from an asphalt kettle unit.

At the Campo site, self-leveling silicones were routinely placed too near the pavement surface, exposing large portions of the material to direct contact by traffic tires. The narrow joint openings (3 mm) where this occurred were believed to be a factor.

Neoprene Compression Seals

The preformed compression seals used in the SPS-4 test sites were supplied by manufacturers in continuous rolls. Most of the seals were installed mechanically using a special installation machine, such as the D.S. Brown Auto Installer shown in figure 20. These machines compressed the seal, coated the seal with a lubricant adhesive, and inserted it into the pavement joint. Typically, the first and last few millimeters of these seals along each joint had to be installed by hand.

Generally speaking, the compression seal installation machines worked well for 9- and 13-mm-wide joints. However, there was much greater difficulty with the installation of compression seals in 6-mm-wide joints. Nearly half of the seals destined for the 6-mm-wide joints at the Heber City site had to be installed by hand.

The Esco PV-687 seals at the Tremonton site were installed by hand, as shown in figure 21. In addition, because of an improperly functioning installation machine, the two compression seals selected for use at the Campo site were also installed by hand using putty knives. The result at the Campo site was several twisted and sunken seals, especially in the 6-mm-wide joints.

Polysulfide Sealant

The self-leveling polysulfide sealant Koch 9050-SL was installed at the Salt Lake City and Heber City test sites. Much like silicone sealant, this material was placed into joints under pressure using a joint sealant pump mounted on a flatbed truck. Although some minor problems

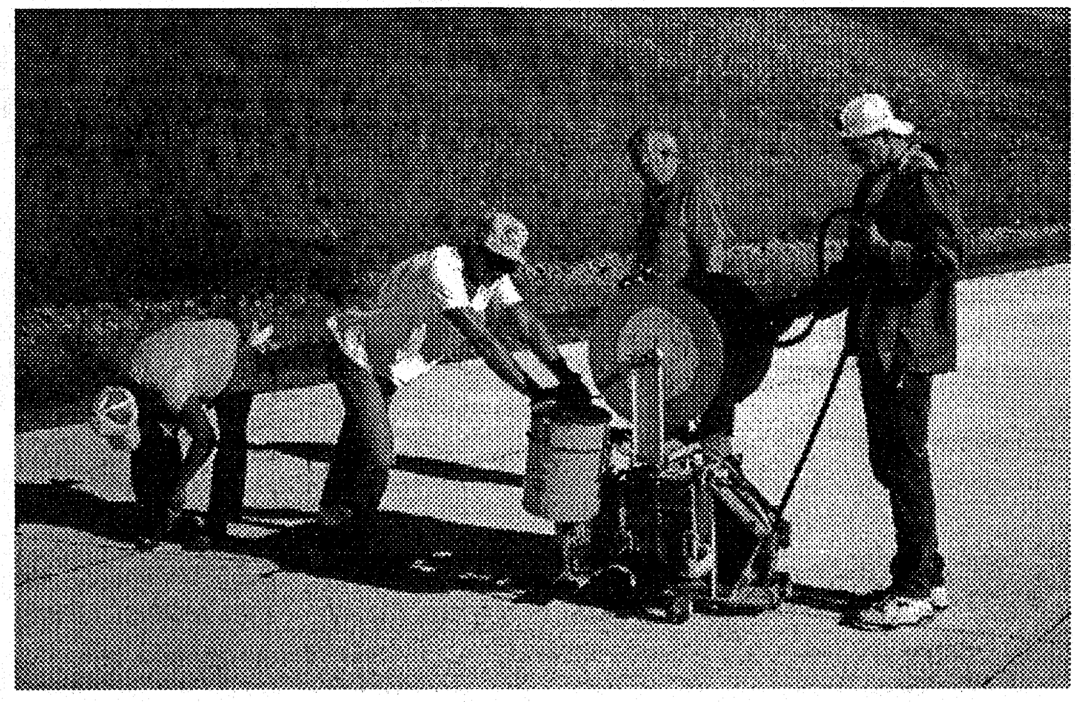

Figure 20. Mechanical installation of neoprene compression seal at Heber City, Utah test site.

Figure 21. Manual installation of neoprene compression seal at Tremonton, Utah test site.

were experienced with the pump during the installation of Koch 9050-SL at Salt Lake City, a much greater problem was experienced when rain washed some of the sealant out of the joints at this site and caused some seals to have low spots. Seals that were washed out were subsequently resealed with new polysulfide material.

Field Data Collection and Analysis

Installation data for each test section in each test site were collected in the field and recorded on SHRP LTPP data collection forms. Among the types of information collected were the following:

- Installation date and time.
- Test section stationing.
- Joint preparation method.
- Joint reservoir dimensions.
- Backer rod material installed.
- Depth to top of backer rod.
- Sealant material installed.
- Depth to top of sealant.

Summaries of most of this information are contained in the six SPS-4 supplement joint seal construction reports (Meier, 1992; Wienrank and Evans, 1995a, 1995b, 1995c, 1995d; Ambroz and Evans, 1996). These reports also describe the results of analyses performed to determine adherence of actual joint reservoir and seal dimensions to the experimental design dimensions. Those analysis results are summarized below.

- Secondary sawcuts—For most sections at each site, joints were sawed to an acceptable tolerance (±1.6 mm) of the specified joint width. Of the 125 test sections comprising the 6 test sites, 101 sections had the majority of joints sawed to within the specified tolerance limits. The vast majority of the 24 sections that didn't meet design specifications consisted of overly wide sawcut joints. The causes of these occurrences were not identified. However, for five sections found to be out of compliance at the Wells site, it was believed that the existing joints were about as wide as the design dimension and that the required secondary sawing (to remove the old sealant and provide a new reservoir) inevitably resulted in excessively wide joint reservoirs.

- Depth to top of backer rod—With the exception of the Campo test sections, backer rods were usually placed to the allowable limits of 13 to 19 mm below the pavement surface. All 18 sections requiring backer rods at the Mesa site and all 11 sections requiring backer rod at Tremonton had a majority of the joints installed with backer rod to within allowable limits. Moreover, 27 of the 39 backer rod sections at Wells, Salt Lake City, and Heber City had a majority of joints with the backer rod placed to acceptable depths. At the Campo site, 7 of the 12 sections requiring backer rod had a majority of the joints with backer rod placed out of tolerance. Overwhelmingly, the backer rods in these sections were placed too high.

- Depth to top of sealant—At all sites, the allowable limits for depth to the top of sealant from the pavement surface were established at 6 and 9 mm. Measurements taken in the field indicated that most sealants were placed to depths outside these limits. At the Mesa, Campo, and Salt Lake City sites, 33 of the 45 sections measured for sealant depth showed that the majority of seals were placed too high (less than 6 mm deep) in the joint, potentially exposing them to traffic. A few sections at Heber City and Tremonton were also observed to have excessively high sealants. In contrast, 7 of the 16 sections measured for sealant depth at Wells had a majority of the joints in which sealant was placed too low (in excess of 9 mm deep).

- Sealant shape factor—An important parameter in the design and construction of field-molded sealants is the sealant shape factor. The shape factor is defined as the ratio of the sealant depth to the sealant width, and it is important because different shape factors result in different levels of stress development for different sealant types during sealant extension. The shape factors that result in the lowest buildup of stresses most often provide better field performance. As examples, silicone sealants generally provide the best performance when placed in a shape factor of about 0.5, whereas hot-applied rubberized asphalt materials generally provide the best performance when placed in a shape factor around 1.0. A summary of the analysis of shape factors at each test site is provided below.

  - At Mesa, two different treatments had mean shape factors outside of the specified design tolerances (0.57 to 1.20 for 9-mm-wide joints, 0.80 to 2.00 for 6-mm-wide joints, and 1.00 to 5.00 for 3-mm-wide joints). One section of Dow 890-SL, placed in 6-mm-wide joints, had a mean shape factor of 0.61, whereas the design shape factor range for this treatment was 0.80 to 2.00. Also, the two sections of Dow 890-SL placed in 3-mm-wide joints had mean shape factors of 0.58 and 0.62. The design shape factor range for this treatment was 1.00 to 5.00. Since silicone has been shown to provide the best performance with a shape factor around 0.5, the performance of these treatments could be better than what the design shape factor would have provided.

  - At Campo, 4 of the 13 test sections measured for seal dimensions had mean shape factors outside of the specified design tolerances (0.29 to 1.60 for 9-mm-wide joints, 0.80 to 2.67 for 6-mm-wide joints, and 0.67 to 8.00 for 3-mm-wide joints). Two sections of Crafco 903-SL placed in 6-mm joints had mean shape factors of 0.77 and 0.71, whereas the design shape factor range for this treatment was 0.8 to 2.67. Also, one section of Crafco 902 placed in 6-mm joints had a mean shape factor of 0.77, slightly under the minimum tolerance of 0.8. Lastly, one section of Crafco 902 placed in 3-mm joints had a mean shape factor of 0.5, whereas the design shape factor range for this treatment was 0.67 to 8.00. Though each of these treatments were considerably thinner than what was designed, their shape factors are closer to the optimal shape factor for silicone sealants.

- At Wells, all of the 14 test sections measured for seal dimensions had mean shape factors within the specified design tolerances (0.29 to 1.60 for 9-mm-wide joints). Most of the measured mean shape factors were around 0.60, which is generally to the advantage of silicone seals. However, in some of these sections (Dow 888, Crafco 902, and Crafco 903-SL, all placed in 9-mm joints), very high standard deviations of shape factor were computed, which means that several of the seals probably had shape factors below the minimum tolerance of 0.29.

- At Tremonton, all of the seven test sections measured for seal dimensions had mean shape factors within the specified design tolerances (0.29 to 1.60). Most of the measured mean shape factors were around 1.00, which is generally very suitable for hot-applied seals, but slightly less suitable for silicone seals.

- At Salt Lake City, all but 1 of the 10 test sections measured for seal dimensions had mean shape factors within the specified design tolerances (0.29 to 1.60 for 9-mm-wide joints and 0.67 to 8.00 for 3-mm-wide joints). A section of Crafco RS 221 had a mean shape factor of 1.85, whereas the design shape factor range for this treatment was 0.29 to 1.60. The replicate section of this treatment had a mean shape factor of 1.46; however, its standard deviation of 0.37 indicates that several of the seals probably exceeded the maximum tolerance of 1.60. Generally speaking, these mean shape factors are too high for optimal performance by hot-applied rubberized asphalt sealant.

  The 3-mm-wide joint design was used in two sections. The mean shape factors of the Dow 890-SL seals placed in these sections were 2.48 and 2.29, both of which were within the design shape factor limits of 0.67 to 8.00. However, these shape factors are considerably higher than the optimal shape factor of 0.5 for silicone sealants, and could result in reduced performance.

- At Heber City, all of the 12 test sections measured for seal dimensions had mean shape factors within the specified design tolerances (0.29 to 1.60 for 9-mm-wide joints and 0.67 to 8.00 for 3-mm-wide joints). However, one section of Koch 9012 placed in
  9-mm joints was computed as having a mean shape factor of 1.37 and a standard deviation of 0.25, which indicates that several of the seals probably had shape factors above the maximum tolerance of 1.60.

  Like the Salt Lake City site, the 3-mm-wide joint design was used in two sections. The mean shape factors of the Dow 890-SL seals placed in these sections were 1.67 and 2.13, both of which were within the design shape factor limits of 0.67 to 8.00. However, these shape factors are considerably higher than the optimal shape factor of 0.5 for silicone sealants, and could result in reduced performance.

Productivity and Cost Data

Because very few records were kept regarding the time, material, labor, and equipment required to saw, clean, and seal each test section, individual estimates of productivity and installation costs for each joint seal treatment were not available. The only productivity data available were from Wells (table 4). In addition, material costs were available from both Wells (table 4) and Mesa (table 5).

Table 4. Material costs and sealant installation times at Wells, Nevada test site (Wienrank and Evans, 1995a).

Material	Sealant Cost	Average Installation Time for One Section, min
Dow 890-SL	\$11.95/L	30
Crafco 903-SL	\$10.73/L	25
Dow 888-SL	\$10.04/L	25
D.S. Brown V-812	\$1.80/m (includes lube & adhesive)	115
Mobay 960	\$11.76/L	27.5
Crafco RS 902	\$10.33/L	40
Dow 888	\$10.83/L	32.5

Table 5. Material costs at Mesa, Arizona test site (Meier et al., 1992)

Sealant Material	Cost, \$/m
Watson Bowman Compression Seal	2.03[a]
Lubricant	0.13
Total	2.16
Elastomer PV-687 Compression Seal	1.90
Lubricant	0.13
Total	2.03
Crafco RS 221 Hot-Applied	0.16
Flush Oil	0.07
Total	0.23
Crafco SS 444 Hot-Applied	0.29
Flush Oil	0.07
Total	0.36
Dow 890-SL	1.64
Dow 888-SL	1.64
Mobay Baysilone 960-SL	1.61
Dow 888	1.34
Crafco 903-SL	1.34

[a] Used in place of Elastomer PV-687.

CHAPTER 3. MATERIAL TESTING

As a check to ensure that the sealants used in the test sites met the specifications maintained by the manufacturers, laboratory material testing was performed. These tests were completed on samples taken from the batches of material shipped to and used at each site. For reasons not reported, not all sealant products placed in the SPS-4 supplemental joint seal sites were tested. Most of the testing was conducted on silicone materials; however, some compression seals and some hot-applied sealants were also tested. This chapter discusses the tests that were performed under the SPS-4 supplemental joint seal studies and presents the results of those tests.

Laboratory Tests Performed

Formal laboratory testing, using SHRP LTPP procedures, was conducted on field-retrieved sealant samples from four of the six SPS-4 test sites. None of the sealants installed at the Campo and Tremonton sites were formally tested. However, the results of material tests performed by the manufacturers of sealants installed at Campo were made available by the manufacturers. Table 6 summarizes, by test site, the types of materials tested, both formally under the SHRP LTPP program and internally by the sealant manufacturers.

The battery of tests performed on each sealant type consisted of general material property tests (e.g., specific gravity, extrusion rate) and performance-related tests (e.g., bond, tensile stress under elongation). Table 7 lists the individual tests performed on each sealant type and the corresponding designated test method and guiding specification.

Table 6. Summary of laboratory testing of SPS-4 supplemental joint seal materials.

Test Site	SHRP LTPP Laboratory Testing	Material Manufacturer Laboratory Testing
Mesa, AZ	Compression seals Hot-applied seals Non-self-leveling silicone seals Self-leveling silicone seals	NA
Campo, CO	NA	Compression seals Non-self-leveling silicone seals Self-leveling silicone seals
Wells, NV	Non-self-leveling silicone seals Self-leveling silicone seals	NA
Tremonton, UT	NA	NA
Salt Lake City, UT	Self-leveling silicone seals	NA
Heber City, UT	Self-leveling silicone seals	NA

Table 7. Summary of laboratory tests performed on various sealant types.

Sealant Type	Test Description	Test Method	Guiding Specification
Non-self-leveling Silicone and Self-leveling Silicone	Tensile stress @ 150% strain	ASTM D 412 (die C)	Georgia DOT 106
	Durometer hardness	ASTM D 2240	Georgia DOT 106
	Bond to PCC mortar	AASHTO T-132	Georgia DOT 106
	Tack-free time	ASTM C 679	Georgia DOT 106
	Extrusion rate	MIL S-8802	Georgia DOT 106
	Specific gravity	ASTM D 792	Georgia DOT 106
	Movement capability and adhesion	ASTM C 719	Georgia DOT 106
	Non-volatiles		Georgia DOT 106
	Elongation at break	ASTM D 412 (die C)	Michigan DOT
Preformed Neoprene	Tensile strength	ASTM D 412 (die C)	ASTM D 2628
	Elongation at break	ASTM D 412 (die C)	ASTM D 2628
	Durometer hardness	ASTM D 2240 (mod.)	ASTM D 2628
	Accelerated aging	ASTM D 573	ASTM D 2628
	Very low-temperature recovery	ASTM D 2628	ASTM D 2628
	Low-temperature recovery	ASTM D 2628	ASTM D 2628
	High-temperature recovery	ASTM D 2628	ASTM D 2628
	Compression-deflection @ 80% nominal width	ASTM D 2628	ASTM D 2628
	Oil swell	ASTM D 471	ASTM D 2628
Hot-Applied PVC-Coal Tar	Penetration	ASTM D 3583	ASTM D 3406
	Flow	ASTM D 3583	ASTM D 3406
	Non-immersed bond	ASTM D 3583	ASTM D 3406
	Water-immersed bond	ASTM D 3583	ASTM D 3406
	Resilience	ASTM D 3583	ASTM D 3406
	Oven-aged resilience	ASTM D 3583	ASTM D 3406
	Tensile adhesion	ASTM D 3583	ASTM D 3406
	Flexibility	ASTM D 3583	ASTM D 3406
Hot-Applied Rubberized Asphalt	Penetration	ASTM D 3407	ASTM D 3405
	Flow	ASTM D 3407	ASTM D 3405
	Bond	ASTM D 3407	ASTM D 3405
	Water-immersed bond	ASTM D 3407 (variant)	ASTM D 3405 (variant)
	Resilience	ASTM D 3407	ASTM D 3405
	Brookfield viscosity		
	Ductility	ASTM D 113	
	Asphalt compatability	ASTM D 3407	ASTM D 3405

Laboratory Test Results

Details of the laboratory testing results for selected materials installed at each site were provided in the six SPS-4 supplemental joint seal construction reports (Meier et al., 1992; Wienrank and Evans, 1995a, 1995b, 1995c, 1995d; Ambroz and Evans, 1996). Summaries of the results, categorized by sealant type, are provided in the sections below.

Non-Self-Leveling Silicone Sealants

Non-self-leveling silicone material batches tested under the SHRP LTPP program included the following:

- Dow 888 at Mesa, Arizona.
- Dow 888 at Wells, Nevada.
- Mobay Baysilone 960 at Wells, Nevada.
- Crafco RS 902 at Wells, Nevada.

Though specific test results for the Dow 888 placed at Mesa were not listed in the construction report, it was reported that this material met the guiding specification for non-self-leveling silicone sealants (Georgia DOT silicone specification 106) (Meier et al., 1992).

The specific test results for the three silicones placed at Wells are presented in table 8. All three sealants met the guiding non-self-leveling silicone specification (Georgia DOT requirements).

The results of tests performed by Crafco on the RS 902 silicone installed at Campo are provided in table 9. This material met the guiding specification (based on Georgia DOT and Michigan DOT requirements) for non-self-leveling silicone sealants.

Self-Leveling Silicone Sealants

Self-leveling silicone material lots tested under the SHRP LTPP testing protocol included the following:

- Dow 888-SL at Mesa, Arizona.
- Dow 890-SL at Mesa, Arizona.
- Mobay Baysilone 960-SL at Mesa, Arizona.
- Crafco RS 903-SL at Mesa, Arizona.
- Dow 888-SL at Wells, Nevada.
- Dow 890-SL at Wells, Nevada.
- Crafco RS 903-SL at Wells, Nevada.
- Dow 888-SL at Salt Lake City, Utah.
- Dow 888-SL at Heber City, Utah.

Table 8. Formal laboratory testing results for non-self-leveling silicone sealants installed at Wells, Nevada test site (Wienrank and Evans, 1995a).

Test Description	Test Method	Georgia DOT Specification	Mobay Baysilone 960	Crafco RS 902	Dow 888
Tensile Stress @ 150% Strain, kPa	ASTM D 412 (die C)	≤ 310	239.4	278.8	247.0
Durometer Hardness, Shore A	ASTM D 2240	10 - 25	12	10	16
Bond to PCC Mortar, kPa	AASHTO T-132	≥ 345	434.7	648.6	579.6
Tack-Free Time, min	ASTM C 679	≤ 90	48	55	51
Extrusion Rate, g/min	MIL S-8802	≥ 75	308	167	196
Non-volatiles, %		≥ 90	94.9	96.2	96.3
Specific Gravity	ASTM D 792	1.1 - 1.5	1.188	1.297	1.488
Movement Capability and Adhesion	ASTM C 719	10 cycles @ ± 50%	Pass	Pass	Pass

Table 9. Material manufacturer laboratory testing results for non-self-leveling silicone sealant installed at Campo, Colorado test site (Ambroz and Evans, 1996).

Test Description	Test Method	Georgia DOT Specification	Michigan DOT Specification	Crafco RS 902
Tensile Stress @ 150% Strain, kPa	ASTM D 412 (die C)	≤ 310		209.1
Durometer Hardness, Shore A	ASTM D 2240	10 - 25		10
Bond to PCC Mortar, kPa	AASHTO T-132	≥ 345		NA
Tack-Free Time, min	ASTM C 679	≤ 90		70
Extrusion Rate, g/min	MIL S-8802	≥ 75		NA
Specific Gravity	ASTM D 792	1.1 - 1.5		NA
Movement Capability and Adhesion	ASTM C 719	10 cycles @ ± 50%		Pass
Elongation at Break, %	ASTM D 412 (die C)		≥ 700	927

NA=Not available.

Specific test results for the four self-leveling silicones placed at Mesa were not listed in the construction report for that site. However, it was reported that only the Dow 888-SL met the guiding Georgia DOT silicone specification (Meier et al., 1992). The Dow 890-SL sealant met all parts of the specification except the Durometer (Shore A) Hardness test, whereby the recorded value of 3 for the material was less than the requirement of 10 to 25. The Mobay Baysilone 960-SL sealant failed the movement capability and adhesion test (10 cycles, ±50%/0% at -18°C). Lastly, the Crafco RS 903-SL sealant failed both the Durometer (Shore A) Hardness test (a test value of 2, which was lower than the 10 to 25 requirement) and the Tack-Free Time test (135 minutes, as compared to a maximum of 90 minutes).

As seen in table 10, two of the three silicones placed at Wells met the guiding self-leveling silicone specification (Georgia DOT requirements). Only the Crafco RS 903-SL did not, as it failed the Tack-Free/Skin-Over Time test (219 minutes, as compared to a maximum of 90 minutes).

Table 11 shows the results of the tests performed on separate batches of Dow 888-SL placed at Salt Lake City and Heber City. As can be seen, the Heber City batch met all parts of the guiding self-leveling silicone specification (Georgia DOT requirements), whereas the Salt Lake City batch failed the requirement for tensile stress at 150 percent strain (322.2 kPa, as compared to a maximum of 276 kPa).

The results of tests performed by Crafco on its RS 903-SL silicone installed at Campo are provided in table 12. As can be seen, this material met the guiding specification for self-leveling silicone sealants (Georgia DOT requirements).

Table 10. Formal laboratory testing results for self-leveling silicone sealants installed at Wells, Nevada test site (Wienrank and Evans, 1995a).

Test Description	Test Method	Georgia DOT Specification	Crafco RS 903-SL	Dow 888-SL	Dow 890-SL
Tensile Stress @ 150% Strain, kPa	ASTM D 412 (die C)	≤ 276	73.8	162.8	73.8
Durometer Hardness (Shore A)	ASTM D 2240		0	7	1
Bond to PCC Mortar, kPa	AASHTO T-132	≥ 276	331.2	427.8	407.1
Tack-Free Time, min	ASTM C 679	≤ 90 (skin over)	219	52	64
Extrusion Rate, g/min	MIL S-8802	≥ 90	1,447	377	326
Non-volatiles, %		≥ 90	96.4	94.3	97.6
Specific Gravity	ASTM D 792	1.1 - 1.5	1.335	1.344	1.318
Movement Capability and Adhesion	ASTM C 719	10 cycles @ ± 50%	Pass	Pass	Pass

Table 11. Formal laboratory testing results for self-leveling silicone sealants installed at Salt Lake City and Heber City, Utah test sites (Wienrank and Evans, 1995c and 1995d).

Test Description	Test Method	Georgia DOT Specification	Dow 888-SL at Salt Lake City, UT	Dow 888-SL at Heber City, UT
Tensile Stress @ 150% Strain, kPa	ASTM D 412 (die C)	≤ 276	322.2	129.0
Durometer Hardness (Shore A)	ASTM D 2240		7	8
Bond to PCC Mortar, kPa	AASHTO T-132	≥ 276	476.1	627.9
Tack-Free Time, min	ASTM C 679	≤ 90 (skin over)	40	48
Extrusion Rate, g/min	MIL S-8802	≥ 90	226	307
Non-volatiles, %		≥ 90	93.5	93.8
Specific Gravity	ASTM D 792	1.1 - 1.5	1.3	1.349
Movement Capability and Adhesion	ASTM C 719	± 50% min	Pass	Pass

Table 12. Material manufacturer laboratory testing results for self-leveling silicone sealant installed at Campo, Colorado test site (Ambroz and Evans, 1996).

Test Description	Test Method	Georgia DOT Specification	Crafco RS 903-SL
Tensile Stress @ 150% Strain, kPa	ASTM D 412 (die C)	≤ 276	199.4
Durometer Hardness (Shore A)	ASTM D 2240		57
Bond to PCC Mortar, kPa	AASHTO T-132	≥ 276	428.5
Tack-Free Time, min	ASTM C 679	≤ 90 (skin over)	49
Extrusion Rate, g/min	MIL S-8802	≥ 90	548
Specific Gravity	ASTM D 792	1.1 - 1.5	NA
Movement Capability and Adhesion	ASTM C 719	10 cycles @ ± 50%	Pass
Elongation at Break, %	ASTM D 412 (die C)		874

NA=Not available.

Compression Seals

Preformed neoprene compression seals tested under the SHRP LTPP laboratory testing protocol included the following:

- D.S. Brown V-687 at Mesa, Arizona.
- Watson Bowman 687 at Mesa, Arizona.
- Watson Bowman 812 at Mesa, Arizona.

Though specific test results for these compression seals were not listed in the Mesa construction report, it was reported that the D.S. Brown V-687 seal met all requirements except those for the High-Temperature Recovery test (70 hours @ 100°C, 50% deflection); the actual value was 80.5 percent and the required minimum value was 85 percent (Meier et al., 1992). Likewise, the two Watson Bowman seals met all requirements except those for the High-Temperature Recovery test. The Watson Bowman 687 seal registered a recovery of 66 percent, whereas the Watson Bowman 812 registered a recovery of 82 percent, both below the minimum requirement of 85 percent.

The results of tests performed by D.S. Brown on their E-437H and V-687 compression seals installed at Campo are provided in table 13. As can be seen, both materials met the guiding specification (ASTM D 2628 requirements).

Table 13. Material manufacturer laboratory testing results for neoprene compression seals installed at Campo, Colorado test site (Ambroz and Evans, 1996).

Test Description	Test Method	ASTM D 2628 Specification	D.S. Brown E-437H	D.S. Brown V-687
Tensile Strength, kPa	ASTM D 412	13,800	18,630	17,478
Elongation at Break, %	ASTM D 412	250	467	467
Durometer Hardness (Shore A)	ASTM D 2240	50 - 60	56	56
High-Temperature Recovery (70 hour @ 100°C, 50% deflection), %	ASTM D 2628	≥ 85	98	91
Low-Temperature Recovery (72 hour @ -10°C, 50% deflection), %	ASTM D 2628	≥ 88	99	97
Low-Temperature Recovery (22 hour @ -29°C, 50% deflection), %	ASTM D 2628	≥ 83	98	89
Compression-Deflection (80% nominal width), kg/mm	ASTM D 2628	≥ 0.063	0.078	0.087

Hot-Applied Sealants

Two hot-applied sealants were tested under the SHRP LTPP laboratory testing protocol. These sealants were as follows:

- Crafco RS 221, a rubberized asphalt sealant placed at Mesa, Arizona.
- Crafco SS 444, a PVC-coal tar sealant placed at Mesa, Arizona.

Though specific test results for these sealants were not listed in the Mesa construction report, it was reported that both materials met their respective specifications (ASTM D 3405 for Crafco RS 221 and ASTM D 3406 for Crafco SS 444) (Meier et al., 1992).

CHAPTER 4. FIELD PERFORMANCE

As discussed in chapter 2, SPS-4 experimental joint sealants were installed at three test sites in 1991, two sites in 1992, and one site in 1995. With the exception of the Campo site, experimental joint seals were inspected for performance four times. These inspections were performed each fall, beginning in 1994 and ending in 1997. Joint seals at the Campo site were inspected three times, beginning in spring 1996 and ending in fall 1997. Table 14 provides a complete listing of the test site inspections (by week) and the corresponding approximate joint seal ages.

Prior to each field inspection, project staff were responsible for contacting the participating State maintenance agency and selecting the days to do the inspection. Normally, each test site required 2 days of inspection, whereby the lanes in which the experimental seals were installed were closed to traffic and a detailed evaluation of the conditions of the sealants and surrounding concrete was performed. Weather hampered the inspections in a few instances, making a third day necessary for completing the inspection.

Performance Data Collection

Several types of performance data were routinely collected in the SPS-4 joint seal evaluations. These performance data primarily consisted of seal failure data and seal distress data, both derived from detailed, visual inspections. Seal failure was defined as a deterioration of the seal material or surrounding pavement that permits moisture or debris to pass below the seal. Seal distress was defined as those seal system deficiencies that result in a reduction in seal performance without inhibiting the seal's ability to resist the infiltration of moisture and debris below the seal. The complete list of failures and distresses evaluated in the field-molded sealants (silicone, hot-applieds, polysulfide) and preformed compression seals are as follows:

Table 14. Summary of SPS-4 test site inspections and corresponding treatment ages.

Inspection No.	Mesa, AZ		Campo, CO		Wells, NV		Tremonton, UT		Salt Lake City, UT		Heber City, UT	
	Week of Inspect.	Age, months	Week of Inspect.	Age, months	Week of Inspect.	Age, months	Week of Inspect.	Age, months	Week of Inspect.	Age, months	Week of Inspect.	Age, months
Installation	3/18-3/31/91		11/15-11/19/95		8/14-8/22/91		10/23-10/26/92		5/19-5/27/92 (SB) 6/29-8/14/92 (NB)		7/8-7/11/91 (EB) 9/23-10/1/91 (WB)	
1	11/20/94	45	4/21/96	5	9/25/94	37	9/18/94	47	9/18/94	25	9/25/94	36
2	2/11/96	60	10/27/96	11	10/22/95	50	11/12/95	61	11/12/95	39	10/22/95	49
3	2/2/97	72	11/2/97	24	10/20/96	62	11/17/96	73	11/17/96	51	10/20/96	61
4	1/25/98	83	—	—	10/12/97	74	11/16/97	85	11/16/97	63	10/12/97	73

Field-Molded Sealants
- Partial-depth adhesion loss.
- Full-depth adhesion loss (failure).
- Partial-depth spalling.
- Full-depth spalling (failure).
- Stone intrusion.
- Partial-depth cohesion loss.
- Full-depth cohesion loss (failure).

Preformed Compression Seals
- Partial-depth spalling.
- Full-depth spalling (failure).
- Twisted/rolled seal (failure).
- Sunken seal (failure).
- Compression set (failure).
- Surface extrusion.
- Gap (failure).

Toward the goal of collecting the required performance data efficiently, consistently, and completely, a two-page joint seal evaluation form was prepared in a format similar to that used in the SHRP H-106 joint resealing experiment. The form contained adhesion loss and cohesion loss tables on one page and spall distress, compression seal distress, and stone intrusion tables on the second page, as illustrated in figure 22. It also contained an overall failure column, whereby the total length of all failures combined was recorded.

Because of the large number of transverse joint seals in each test section—often between 25 and 30—a statistical sampling plan was devised to permit the field survey crew to evaluate a representative subset of the joint seals without introducing bias into the evaluation results. In this sampling plan, 6 sets of 12 random joint numbers between 1 and 30 were generated using a random number generator. Each set of 12 random numbers was then randomly assigned to each test section at a test site. In this way, a semi-random joint selection pattern was established that would allow for the consistent evaluation of 12 joint seals within each section at a given site.

During each field inspection, each randomly selected transverse joint seal was examined for locations of failure and distress within twelve 0.305-m segments along the joint. Each identified failure or distress location was then measured (with the aid of two 1.8-m folding rulers) and recorded (in inches) on the evaluation form according to the corresponding joint number and position. In the case of adhesion and spall failures and distresses, the side of the joint (approach or leave) was also noted.

For hot- and cold-applied formed-in-place sealants, the overall failure length was identified as the total length of joint seal where moisture and debris were able to bypass the seal as a result of full-depth adhesion failure, cohesion failure, or spall failure. The same definition was applied to neoprene compression seals; however, failure modes consisted of spall failure, twisting, compression set, gap, and sunken seal.

Joint ID	Pos	Adhesion Loss						Tensile Failure		Construction Problems						Overall Adh/Coh Failure, in
		Ptl. Left, in	Ptl. Right, in	Ptl. Overall, in	Full Left, in	Full Right, in	Full Overall, in	Ptl., in	Full, in	Sunk Ptl., in	Sunk Full, in	Missing Seal, in	<0.06 in thick, in	Tooling Failure, in	High Seal, in	
04J421401	1															
04J421401	2	2	2	3												
04J421401	3	4	5	9												
04J421401	4				3	5	5	2	1							6
04J421401	5															
04J421401	6															
04J421401	7															
04J421401	8															
04J421401	9															
04J421401	10				3	2	5									5
04J421401	11															
04J421401	12															

Joint ID	Pos.	Sliver Spall Distress						PCC Edge Failure			Compression Seal Distress					Overall System Failure, in
		Ptl. Left, in	Ptl. Right, in	Ptl. Overall, in	Full Left, in	Full Right, in	Full Overall, in	Full Left, in	Full Right, in	Full Overall, in	Twist/ Roll, in	Sunk >0.5 in, in	Comp. Set, in	Gap, in	Comp. Overall, in	
04J421401	1							11		11						
04J421401	2		1	1												
04J421401	3		1	1												
04J421401	4															6
04J421401	5		1	1												
04J421401	6															
04J421401	7		1	1		1	1									1
04J421401	8															
04J421401	9		1	1												
04J421401	10															5
04J421401	11															
04J421401	12															

1 in = 25.4 mm

Figure 22. SPS-4 supplement joint seal performance evaluation form.

To evaluate the resilience, adhesive properties, and cohesive properties of the field-molded seal materials, two field tests were completed: the coin test and the pull-out test. These tests were performed as specified in the SHRP H-106 *Evaluation and Analysis Plan (EAP)* (Evans et al., 1992). Coin tests were completed on hot-applied and silicone sealant materials, and pull-out tests were carried out on hot-applied, silicone, and polysulfide sealants. The coin test is an indicator of sealant resiliency at the testing temperature, and the pull-out test reveals the adhesive and cohesive properties of sealant materials in the joints. Due to time constraints, coin tests and pull-out tests were performed only at the Campo site. The IA-VAC joint seal vacuum testing device was also used on randomly selected joint seals at the Campo site. A representative of the Colorado DOT performed the IA-VAC testing.

Once all of the performance data for a particular test site and field inspection were collected, the data were manually entered into Microsoft Access®, which served as the database manager for the SPS-4 supplemental joint seal experiment. The entered data were carefully checked for accuracy and corrections were made as necessary.

Field Performance Results

The bottom-line assessment of joint seal performance in this study is based on the percentage of total joint length that has experienced a failure of one type or another. This percentage of failure is computed using the following equation:

$$\%Fail = (L_{fail} / L_{total}) \times 100\% \qquad \text{(Eq. 1)}$$

where:
$\%Fail$ = Percentage of joint seal failed, %.
L_{fail} = Length of failed joint seal, mm.
L_{total} = Total length of joint seal, mm.

In most of the reporting contained herein, joint seal effectiveness is discussed. Joint seal effectiveness is the opposite of joint seal failure, and is computed as follows:

$$\%Eff = 100\% - \%Fail \qquad \text{(Eq. 2)}$$

where:
$\%Eff$ = Percentage of effective joint seal, %
$\%Fail$ = Percentage of joint seal failed, %.

As seen in figure 23, a comparison by test site of the overall performance of the transverse joint seals gives an indication of the rate of joint seal deterioration at each site. Though these performance trends are based on the individual performance trends of different groups of joint seal treatments, the greatest deterioration rates have been at the three Utah sites, whereas the lowest deterioration rates have been at the Mesa and Wells sites.

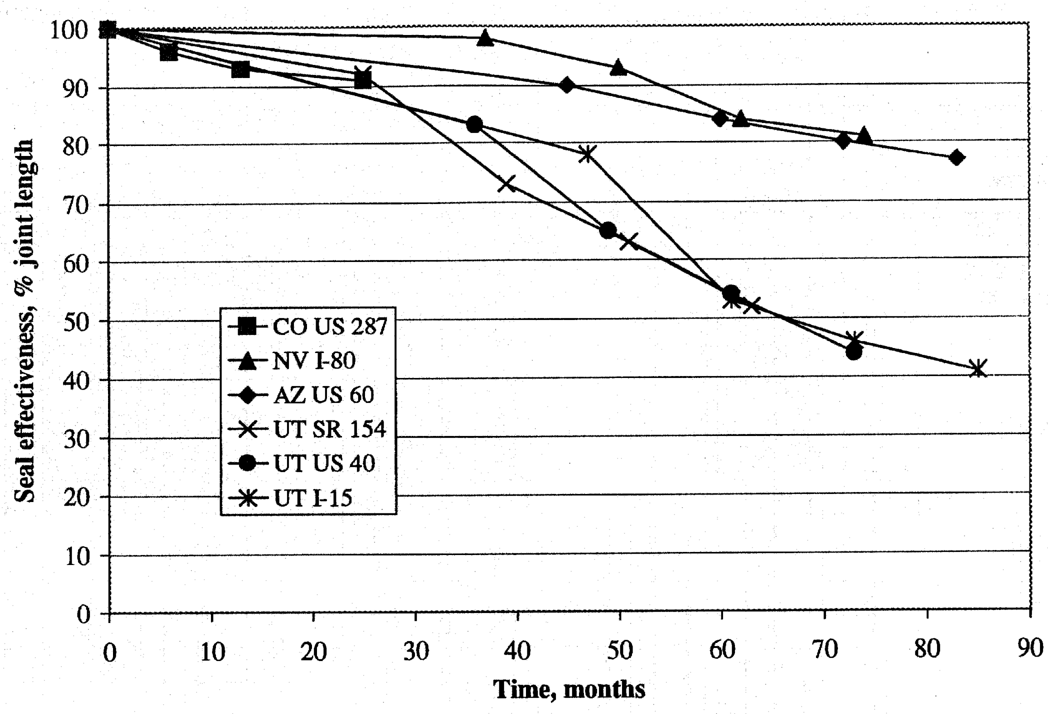

Figure 23. Overall performance of primary transverse joint seals at each test site.

Transverse Joint Seals

The overall effectiveness levels of transverse joint seals stemming from the 1997-1998 round of test site inspections are shown in table 15. As can be seen, several of the sealants have performed well, but many have performed very poorly. Based on the seal performance rating categories developed by Belangie and Anderson (1985) and shown in table 16, 26 of the 56 treatments have performed favorably (≥80 percent of the joint length has not failed), whereas 22 have reached "failed" status (<50 percent of the joint length has not failed). Seven treatments exhibited mediocre performance at the time of the 1997-1998 inspections, and one showed poor performance.

Figures 24 through 29 show, by test site, the overall percentage of failure that each treatment exhibited at the time of the 1997-1998 field inspections. These figures also show the types and percentages of individual failure modes contributing to the overall failure percentage. As can be seen, the predominant modes of failure varied by sealant type and by test site. Generally speaking, the main mechanism of failure in hot-applied seals (e.g., Crafco RS 221, Koch 9012) was adhesive failure, as illustrated in figure 30. Cohesive failure, which can also be seen in figure 30, was significant in some of the seals.

Table 15. Overall effectiveness levels of SPS-4 transverse joint seal treatments following 1997-1998 field inspection round.

Sealant Material	Joint Config.	Overall Effectiveness, % joint length					
		Mesa, AZ (US 60)	Campo, CO (US 287)	Wells, NV (I-80)	Tremonton, UT (I-15)	Salt Lake City, UT (UT 154)	Heber City, UT (US 40)
Crafco RS 221	C	10.7				42.4	
Crafco SS 444	C	31.7					
Crafco 902	A		97.5				
	B		97.1				
	C		98.8	84.3			
	G		96.2				
Crafco 903-SL	A		85.4				
	B		97.7				
	C	98.0	99.0	87.0			
Dow 888	C	98.9		94.2[a]		77.7	15.9
Dow 888-SL	C	97.7		90.1	48.1	72.6	19.2
Dow 890-SL	A	96.5			79.1	25.6	32.3
	B	98.4					
	C	98.8		89.3			
	E				80.9[b]	60.2	67.6
DS Brown E-437H	B		65.7[b]			21.3	73.7
DS Brown V-687	C	29.7	82.5[b]			69.9	93.2
DS Brown V-812	D			35.6			
Koch 9005	C				9.2		49.2
Koch 9012	C				0.0	30.1	44.0
Koch 9050-SL	C					18.2	0.1
Kold Seal	C				1.3		
Mobay 960	C			85.6	93.7		
Mobay 960-SL	C	96.3					
Roshek	A				14.8[b]		
Esco PV 687	C				21.0		
Watson Bowman 687	C	87.2[b]					
Watson Bowman 812	C	90.2[b]					
Polyethylene	F			0.0[b]			

[a] Based on three replicate sections.
[b] Based on one replicate section.

Joint Configuration/Construction
A. Standard saw, 3-mm joint width.
B. Standard saw, 6-mm joint width.
C. Standard saw, 9-mm joint width.
D. Standard saw, 13-mm joint width.
E. Soff-Cut saw, 3-mm joint width.
F. Undisturbed.
G. Standard saw, 9-mm beveled joint.

Table 16. Summary of performance ratings.

Rating	Effectiveness Level, %	Number of Treatments
Very good	90 to 100	18
Good	80.0 to 89.9	8
Fair	65.0 to 79.9	7
Poor	50.0 to 64.9	1
Very poor (failed)	0 to 49.9	22

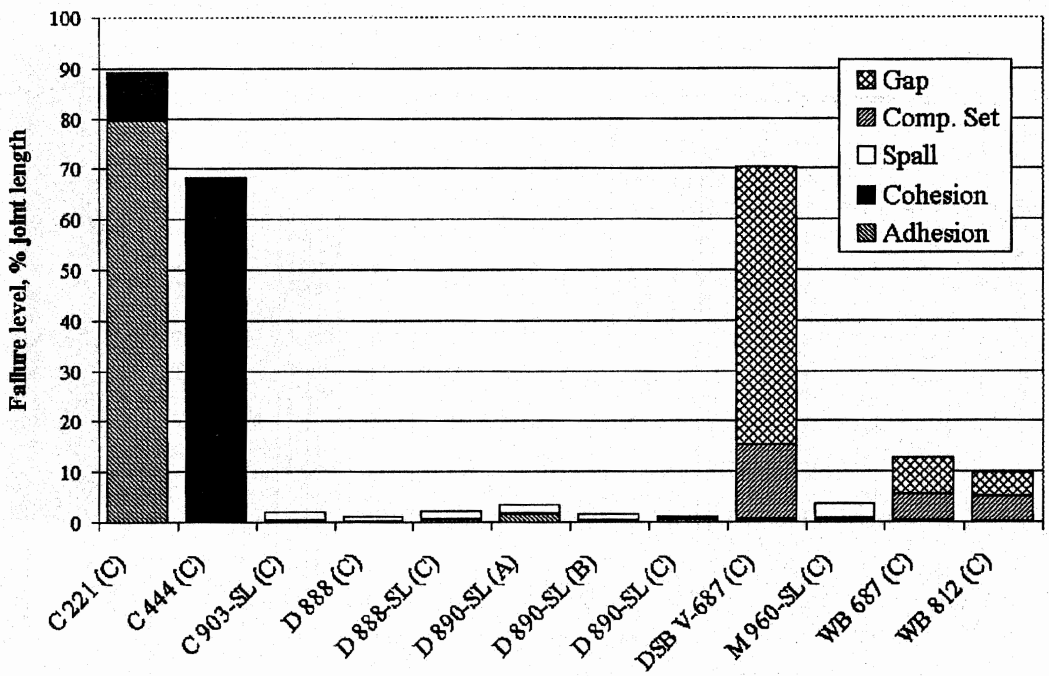

Figure 24. Overall failure of transverse joint seals at Mesa, Arizona test site.

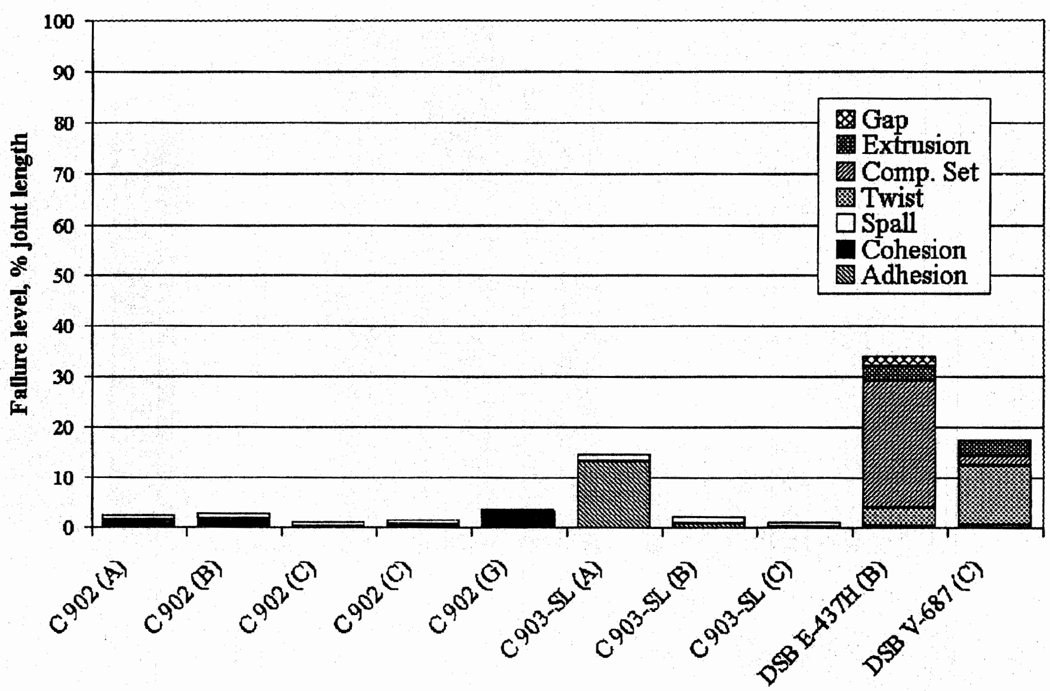

Figure 25. Overall failure of transverse joint seals at Campo, Colorado test site.

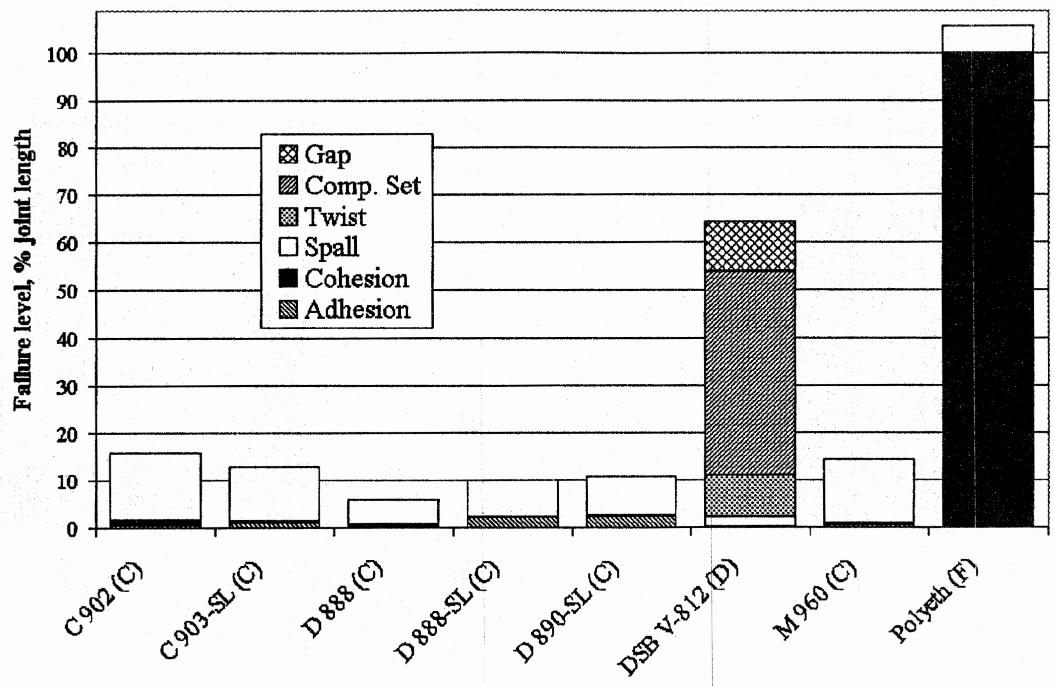

Figure 26. Overall failure of transverse joint seals at Wells, Nevada test site.

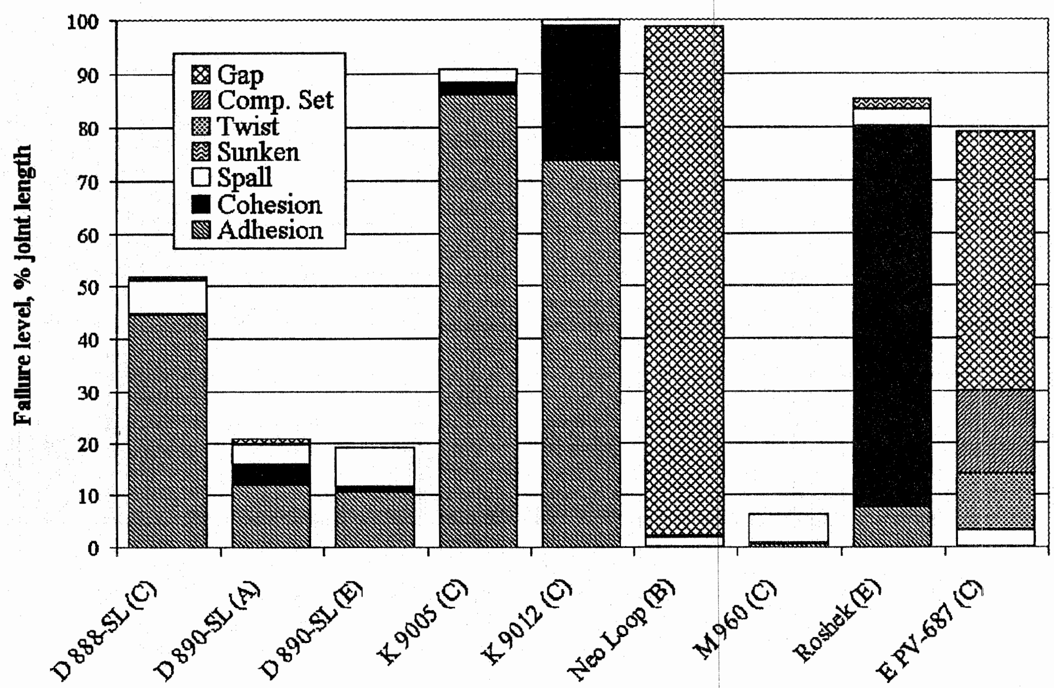

Figure 27. Overall failure of transverse joint seals at Tremonton, Utah test site.

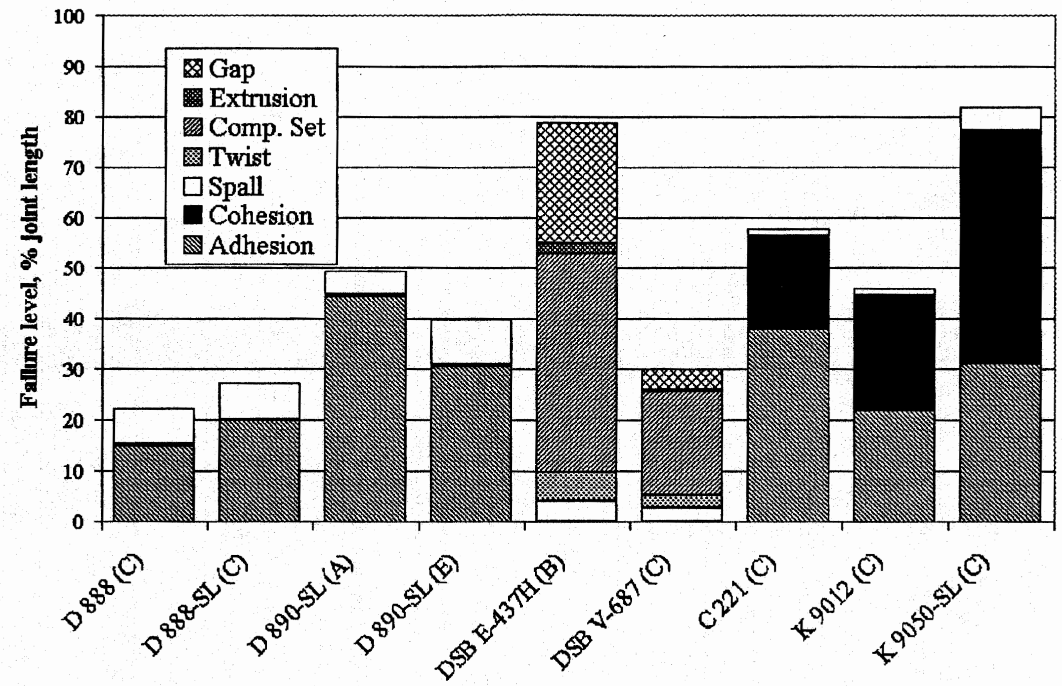

Figure 28. Overall failure of transverse joint seals at Salt Lake City, Utah test site.

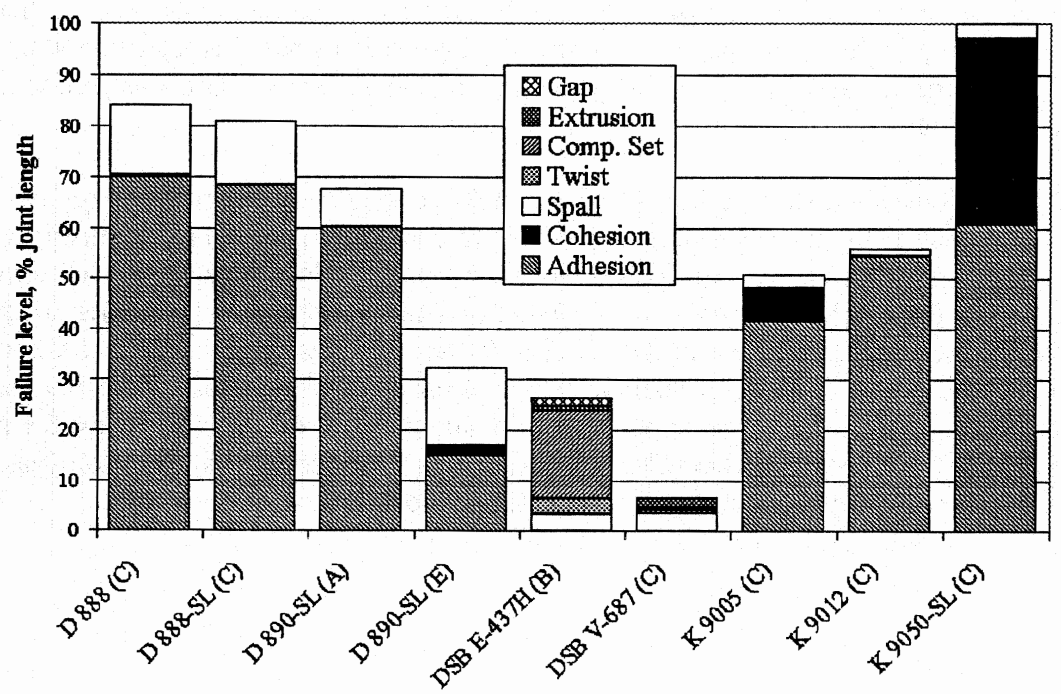

Figure 29. Overall failure of transverse joint seals at Heber City, Utah test site.

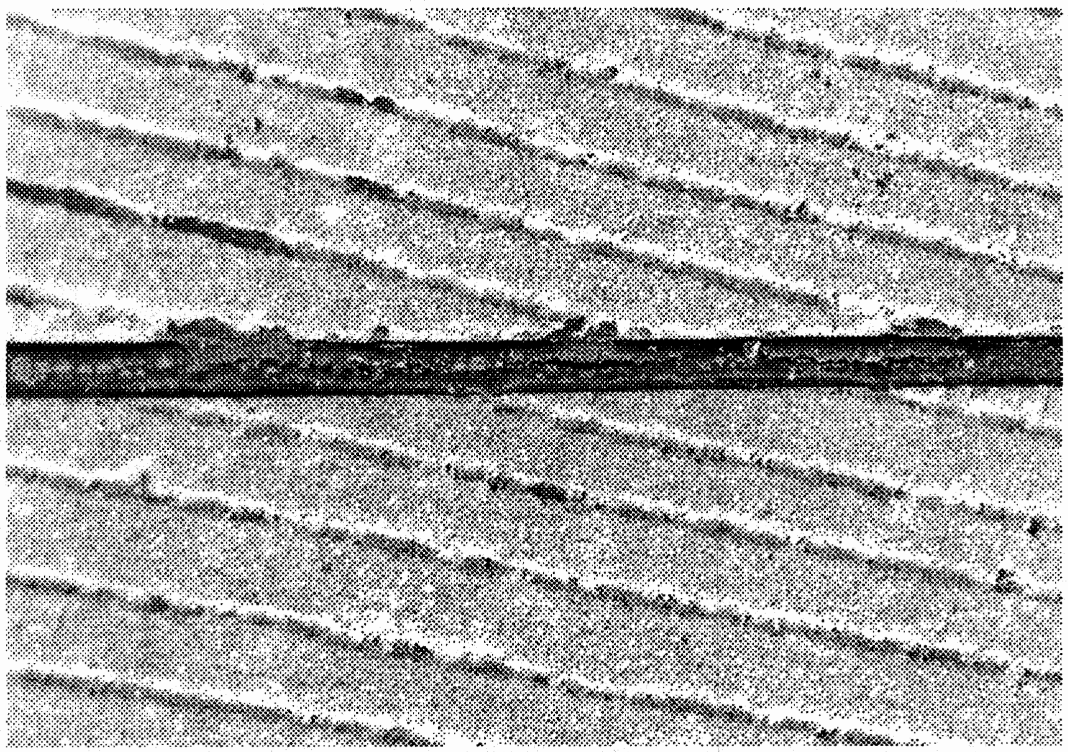

Figure 30. Adhesion and cohesion failure in hot-applied rubberized asphalt seal.

For the non-self-leveling silicone seals, the primary failure mode varied. At a majority of the sites, spall failure (figure 31) comprised most of the failure in these seals, whereas at other sites, adhesive failure was the controlling mechanism. Similar performance characteristics were observed with the self-leveling silicone sealants, except that adhesive failure was predominant at the majority of sites.

The most common failure modes for the compression seals were compression set and gap failure. In compression set, the neoprene web structure loses its ability to exert outward pressure as a result of being in a state of compression for very long periods of time. Thus, when the joint opens, the seal loses contact with the joint sidewall and an opening in the seal system is created that allows infiltration of moisture or debris. Gap failure, which is closely related to compression set, occurs when joints open wider than the compression seal is able to span, and stones work their way between the edge of the compression seal and the edge of the joint. When the joint contracts, the stones remain between the seal and the joint edge and allow water to bypass the edge of the seal. Figure 32 illustrates the gap phenomenon.

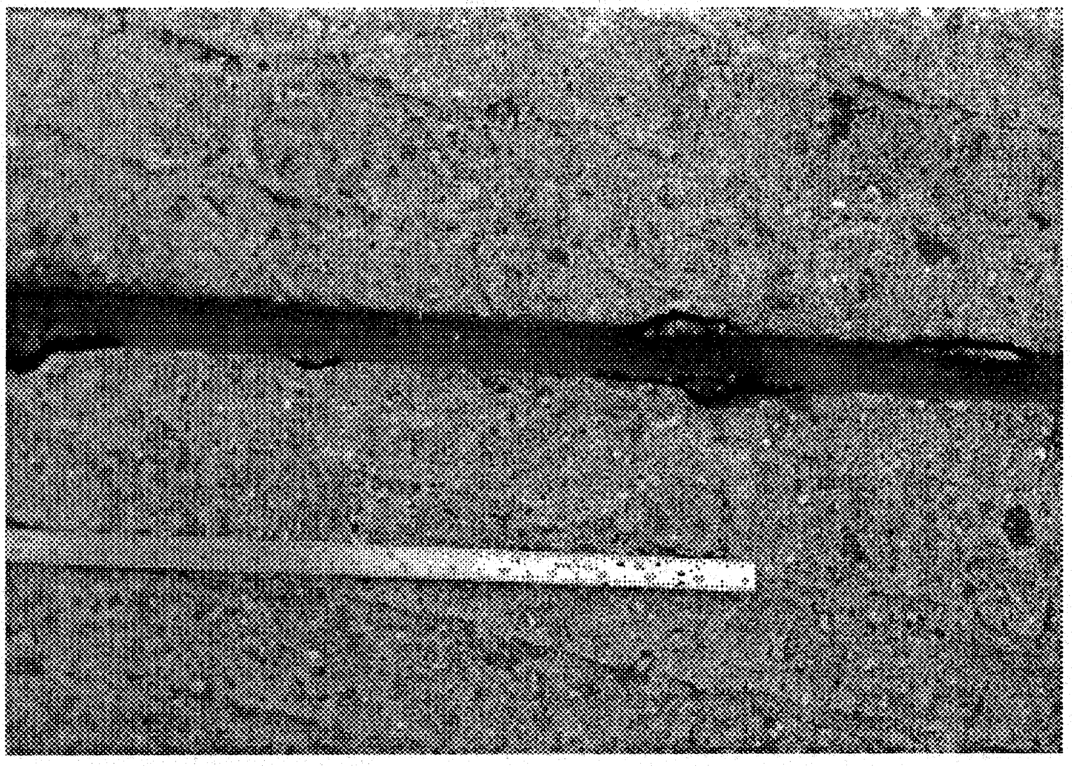

Figure 31. Spall failure in self-leveling silicone seal.

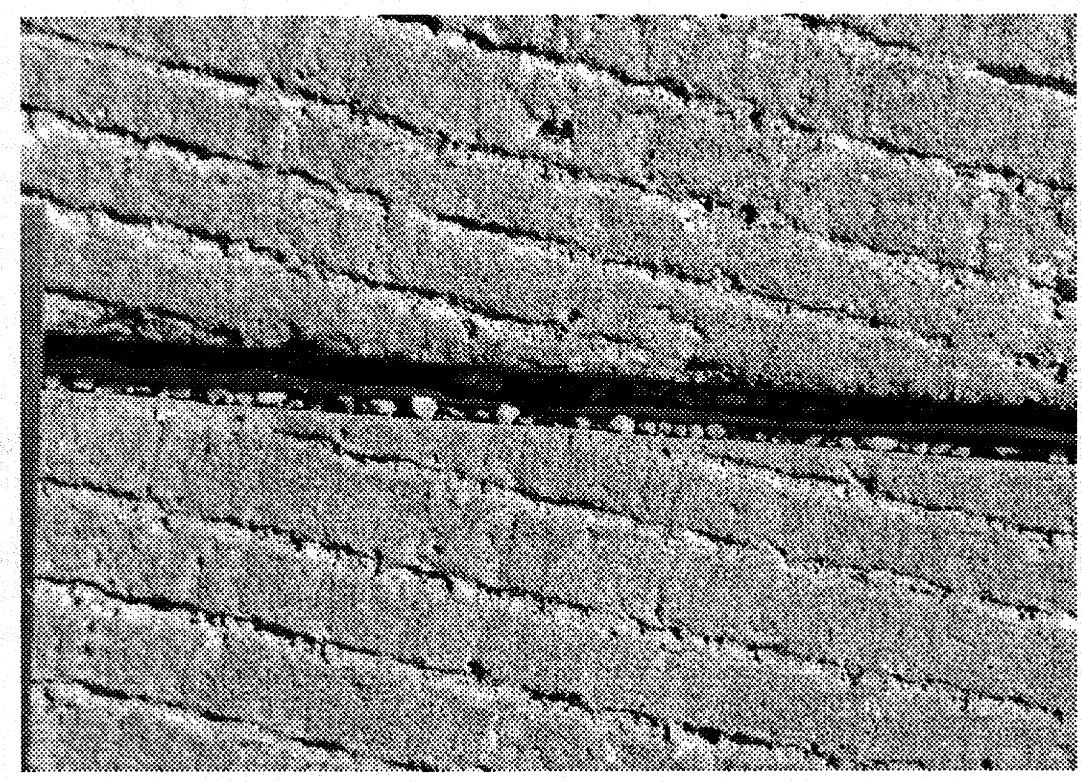

Figure 32. Gap failure in preformed neoprene compression seal.

Longitudinal Joint Seals

Longitudinal joints were sealed with the same material as the transverse joints at the Mesa and Wells sites, and similar evaluations were conducted on these seals. The overall failure levels and failure mode breakdowns for each seal type placed at these two sites are displayed in figures 33 and 34. For the most part, the failure levels and modes for these seals are similar to those of the transverse joint seals. The primary exception is that the polyethylene sealant placed at the Wells site is performing significantly better in the longitudinal joints than in the transverse joints. This can probably be attributed to less joint movement at the longitudinal joint.

Overall Sealant Material Performance

Hot-Applied Rubberized Asphalt Seals

Hot-applied rubberized asphalt sealants meeting the ASTM D 3405 specification were installed at all sites except Wells and Campo. The products installed were Crafco RS 221 and Koch 9005, and the average effectiveness level for this material type as a transverse joint sealant following the 1997-1998 field inspection round was about 28 percent. In longitudinal joints at the Mesa site, the average effectiveness of this material type was 22 percent. Adhesion failure accounted for about 85 percent of the total failure in these materials placed in transverse joints. The best performance of rubberized asphalt sealants was obtained at the Salt Lake City and Heber City sites, with much worse performance at the Mesa and Tremonton sites.

The performance of similar seals placed in the SHRP H-106 joint resealing experiment was considerably better (Evans et al., 1999). After approximately 7 years, Koch 9005, placed recessed in sawn joints at five U.S. test sites, had an average effectiveness of about 72 percent. Crafco RS 221 placed recessed in sawn joints at a site in Phoenix, Arizona had an effectiveness of 57 percent after 7 years. It is believed that the level of joint cleaning is a major factor in the performance differences between the SPS-4 hot-applied seals and the H-106 hot-applied seals. With the exception of the Mesa site where joints were sandblasted, waterblasted, and airblasted, the cleaning effort for the hot-applied seals at the other SPS-4 sites (Salt Lake City, Tremonton, and Heber City) was not to the level used in the H-106 sites (sandblast and airblast).

Hot-Applied PVC-Coal Tar Seals

ASTM D 3406 hot-applied PVC-coal tar sealants were placed in the Mesa and three Utah test sites, using either Crafco SS 444 or Koch 9012. The average effectiveness of these materials placed in transverse and longitudinal joints was 32 and 53 percent, respectively. Full-depth adhesion loss was the predominant failure mode, as it comprised 55 percent of the overall failure in transverse seals. Cohesion failure was also a significant contributor, particularly at the Mesa site, where possible overheating of the sealant prior to installation may have altered the properties of the Crafco SS 444 in one of the replicates.

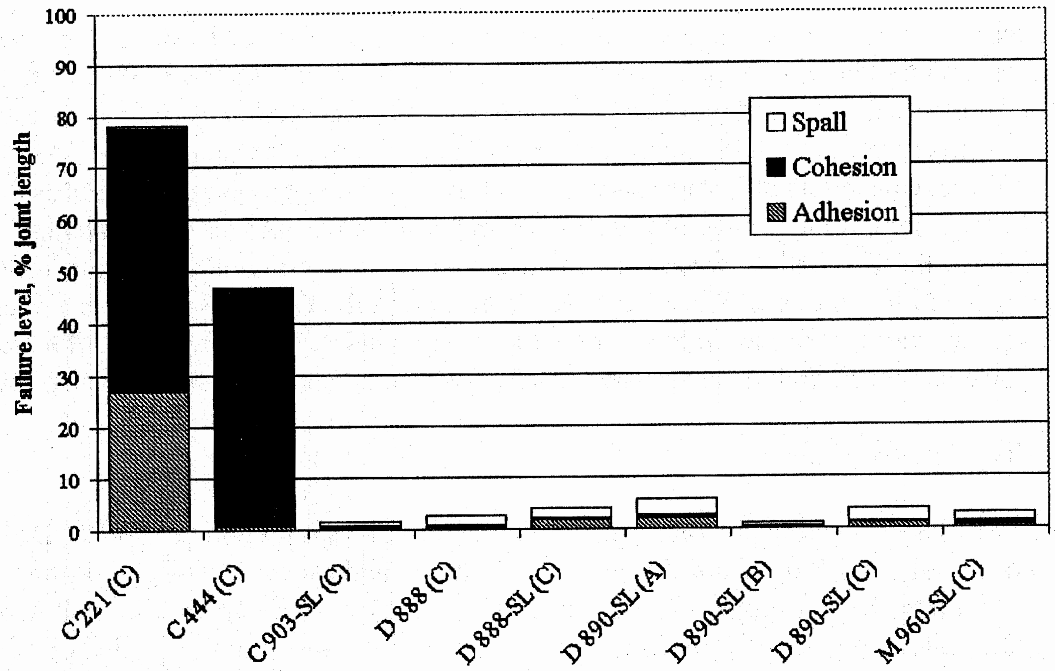

Figure 33. Overall failure of longitudinal joint seals placed at Mesa, Arizona test site.

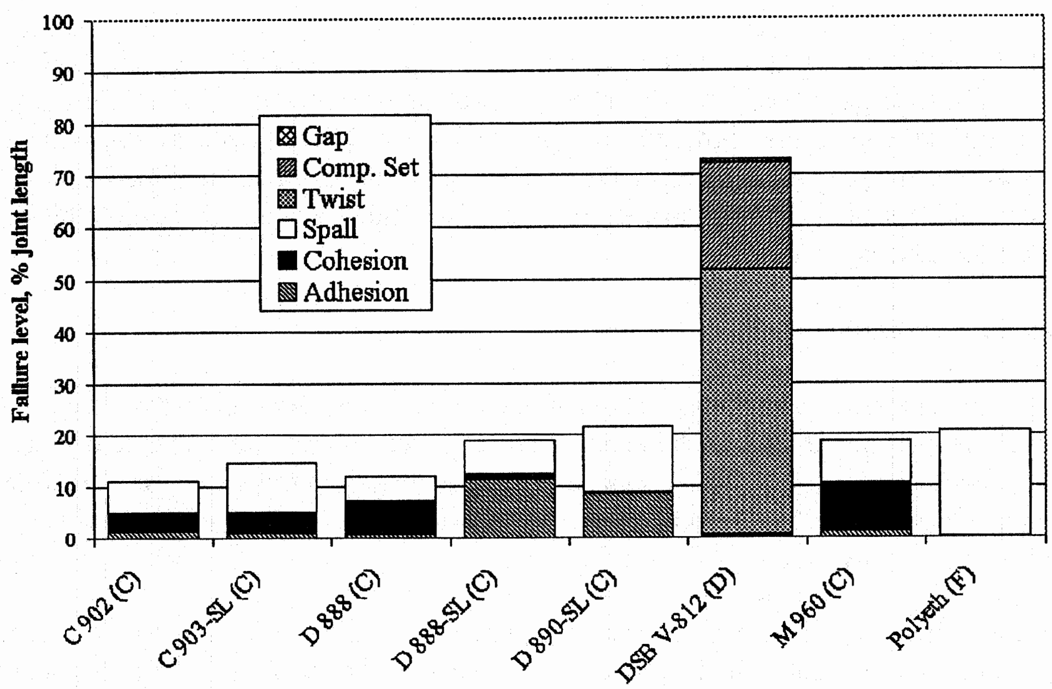

Figure 34. Overall failure of longitudinal joint seals placed at Wells, Nevada test site.

Non-Self-Leveling Silicone Seals

Non-self-leveling silicone sealant products from Dow, Crafco, and Mobay were placed at all six test sites, and this material type's performance has arguably been the best. Of 11 total treatments, only 1 exhibited unfavorable performance (<80 percent effectiveness) in the 1997-1998 field inspections. Dow 888, placed in 9-mm joints at Heber City, experienced considerable adhesion failure, causing its effectiveness rating to drop to 15 percent (joint cleanliness may have been a factor in this failure). Inclusion of this treatment in the calculation of the average effectiveness of the 11 standard silicone treatments resulted in a rating of 85 percent, whereas exclusion resulted in a rating of 92 percent. Not considering the Dow 888 placed at Heber City, the predominant mode of failure in this material type was spall failure (56 percent of total failure); however, considerable percentages of adhesive and cohesive failure were also observed.

Self-Leveling Silicone Seals

A total of 21 self-leveling silicone sealant treatments, consisting of Dow 888-SL, Dow 890-SL, Crafco 903-SL, and Mobay 960-SL placed in 3-mm (standard and Soff-Cut), 6-mm, and 9-mm sawed joints, were installed at the six test sites. Of these 21 treatments, 4 exhibited poor or fair performance (50.0 to 79.9 percent effectiveness) and 4 more exhibited failed performance (<50.0 percent effectiveness) in the 1997-1998 field inspections. These eight unfavorably performing treatments were located at the three Utah sites, and the predominant failure mode was adhesive failure (97 percent of total failure). Among the 13 favorably performing treatments, the primary failure type was spall failure (56 percent of total failure), with considerable percentages of adhesive and cohesive failure also observed.

Self-Leveling Polysulfide Seals

Koch 9050-SL one-part polysulfide sealant was installed at the Salt Lake City and Heber City sites. The average effectiveness level of this sealant after the 1997-1998 field inspections was 9 percent, with a slightly higher percentage of adhesive failure than cohesive failure. Apart from the proprietary sealant installed at Tremonton, this material performed the worst of those placed at the six test sites. During inspection, the polysulfide sealant was found to be very stiff with very little extension ability.

Preformed Compression Seals

Neoprene compression seal materials manufactured by D.S. Brown, Watson Bowman, Esco, and a fourth manufacturer were installed at all six sites. In general, performance of this material type was mixed, as 4 of the 12 treatments performed favorably at the time of the 1997-1998 field inspections and 5 reached failed status. The average effectiveness level of this seal type was 56 percent.

The one-celled Kold Seal Neo Loop seal (figure 35), installed at Tremonton, performed very poorly, with only 1 percent of its length still effective after the 1997-1998 field inspections. The primary mode of failure in this product was gap failure, which is believed to be partly the result of the seal's design and the roadway conditions. The seal has a bulb at its surface that projects

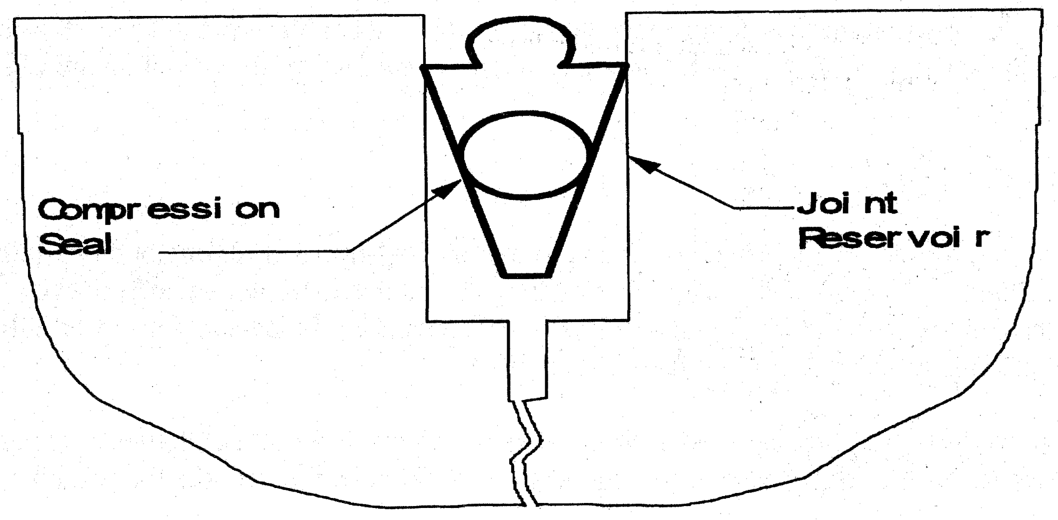

Figure 35. Kold Seal Neo Loop compression seal design.

above the top of the main seal flanges. Small stones and sand wedged between the bulb and the joint edges when the joints were at their widest opening. In the summer, the joints closed to a smaller width, but the stones between the bulb and the joint walls remained in place. Because the bottom of the seal was allowed to compress inward toward the center of the joint, a gap developed between the seal flanges and the joint edge. In some cases, the width of the gap was nearly 3 mm, thus allowing the infiltration of water and debris into the joint.

The four-cell Esco PV-687 compression seal, installed at Tremonton, experienced considerable gap failure, as well as some compression set and twist failures. As a result, its effectiveness during the 1997-1998 field inspections fell to 21 percent.

D.S. Brown compression seals of various widths were used at all but the Tremonton site. The E-437H seal was used in 6-mm joints at three sites with mixed results. At Heber City, the effectiveness of this product remained relatively high, whereas at Salt Lake City, Utah, failure was reached. At the 2-year-old Campo site, effectiveness dropped to 65 percent. Compression set comprised approximately 54 percent of the overall failure and gap failure comprised 20 percent of the overall failure. The V-687 seal was installed in 9-mm joints at the above three sites and Mesa. This product's effectiveness was very low (29 percent) at Mesa, mostly as a result of gap failure and compression set. The seal performed much better at the Campo, Salt Lake City, and Heber City sites, with effectiveness levels ranging from 69 to 93 percent at the time of the 1997-1998 field inspections. Primary modes of failure of this product varied by test site, with compression set being the predominant factor at Salt Lake City and twisting, which occurred during installation, the main factor at Campo. The V-812 seal, placed in 13-mm joints at Wells, received an effectiveness rating of 35 percent in the 1997-1998 field inspections. The primary mode of failure was compression set, with considerable percentages of twist and gap failure also recorded.

Finally, two Watson Bowman seals, WB-687 and WB-812, were installed in 9-mm joints at the Mesa site. Both of these products have performed favorably after 83 months of service. Compression set and gap failure each comprised about 50 percent of the overall failure of these seal products.

Miscellaneous Seals

In the final round of field inspections, the proprietary sealant material provided by Mike Roshek (Utah DOT) and installed at the Tremonton site exhibited 14 percent effectiveness. Full-depth cohesion loss was the predominant failure mechanism for this sealant, with some adhesive failure, spall failure, and sunken seal failure also noted.

The polyethylene sealant installed at Wells in 1980 showed 0 percent effectiveness long before the final round of field inspections. The vast majority of the failed length was the result of cohesive failure.

Joint Configuration Performance

Comparison of the effectiveness levels of the various silicone seal treatments indicate limited potential performance differences with respect to joint configuration. For instance, seals installed at the Mesa site exhibited very little difference in performance when installed in 3-, 6-, and 9-mm-wide joints—effectiveness ranged from 96.5 to 98.8 percent. Also, at the Campo site, where Crafco 902 standard silicone and Crafco 903-SL self-leveling silicone were installed in 3-, 6-, and 9-mm-wide joints, effectiveness levels after 24 months remained very high and fairly similar to one another. Even the Crafco 902 seal placed in a 9-mm-wide beveled joint showed comparable performance.

Comparison of the Dow 890-SL self-leveling silicone seals placed in conventionally sawed and Soff-Cut sawed 3-mm joints at the three Utah sites indicates a possible difference in performance trends. At the Salt Lake City and Heber City sites, seals placed in the Soff-Cut joints showed much better performance than those placed in conventional joints. Similar performance by these two types of seals was observed at the Tremonton site.

CHAPTER 5. DATA ANALYSIS

As stated in chapter 1, the primary objective of this experimental study was to determine the sealant material–joint configuration combinations that perform best in newly constructed pavements. To accomplish this objective, statistical analyses were conducted on the field performance data to identify differences in performance among the various experimental joint seal treatments installed at each site. This chapter describes the statistical methods used to analyze the various types of performance data and presents the results of the analyses.

Statistical Methodology

The SPS-4 supplemental joint seal test sites were designed for a randomized block design analysis with the following two factors: treatments and position along the joint. Two replicates of 12 joints sealed using unique treatments comprised the blocks for analysis of seal performance at each site. Analyses of variance were performed on both the current (1997-1998) joint seal effectiveness levels and the service lives of the experimental seals, as defined by the time required for a sealant to reach 75 percent effectiveness, given its historical effectiveness trend.

Analysis of field performance data was conducted using SAS® statistical software version 6.12. In preparation for statistical analysis, performance data were compiled in spreadsheets, verified, and converted to American Standard Code for Information Interchange (ASCII) format. SAS® command files were prepared for each analysis, instructing the program how to read the ASCII data, what types of statistical analysis to perform, and what form of output was desired.

The SAS® General Linear Model (GLM) procedure with the multivariate analysis of variance (MANOVA) option was used for the analysis of treatment performance. This procedure uses the mean distress values and variability associated with each distress or failure to determine if the performance of two or more of the treatments is statistically different. The procedure was run in conjunction with the Tukey studentized range grouping method, which groups treatments of similar performance and ranks both the groups and the treatments within each group.

Analysis of variance yields a probability rating between 0 and 1 that the values of each distress are the same for each replicate, treatment, and position. For example, if there is no significant difference at one site between the adhesion failure of all treatments, the rating would be near 1. If, however, a significant difference exists between two or more of the treatments, the rating would be near 0. The ratings used in this study were based on a Type IV mean square, with Replicate*Treatment as an error term. Also, probability ratings of 0.05 were used to indicate the existence of significant differences, based on a 95 percent confidence level.

Analysis of Variance of Current Performance

One way to evaluate the performance characteristics of different joint seal treatments is to statistically analyze the most recently documented effectiveness levels. This type of "snapshot" or

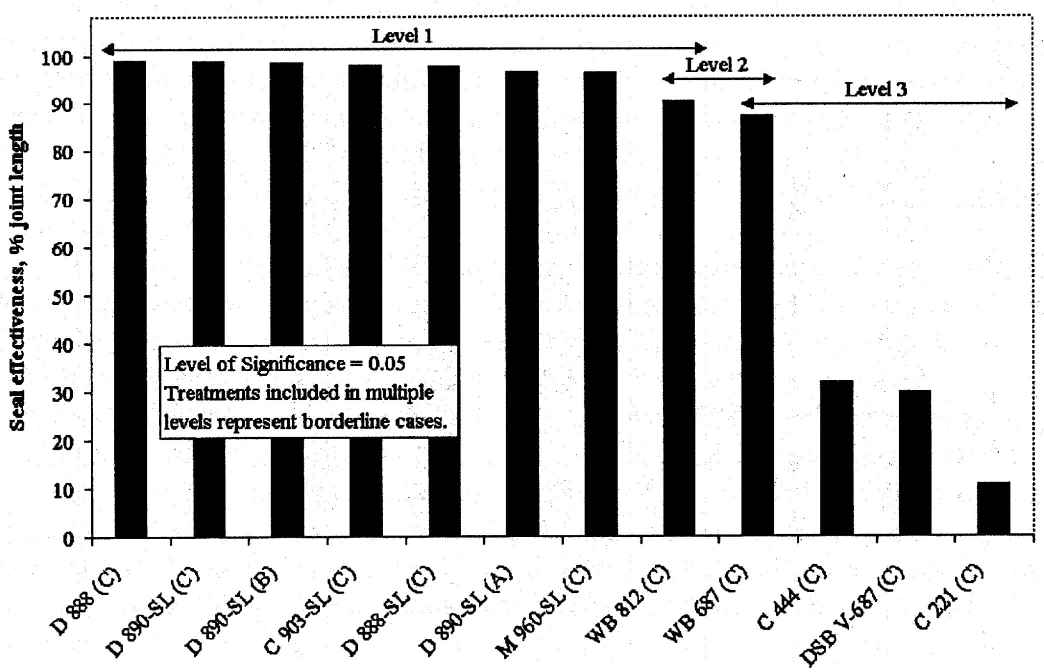

Figure 36. Overall effectiveness groupings for Mesa, Arizona transverse joint seal treatments.

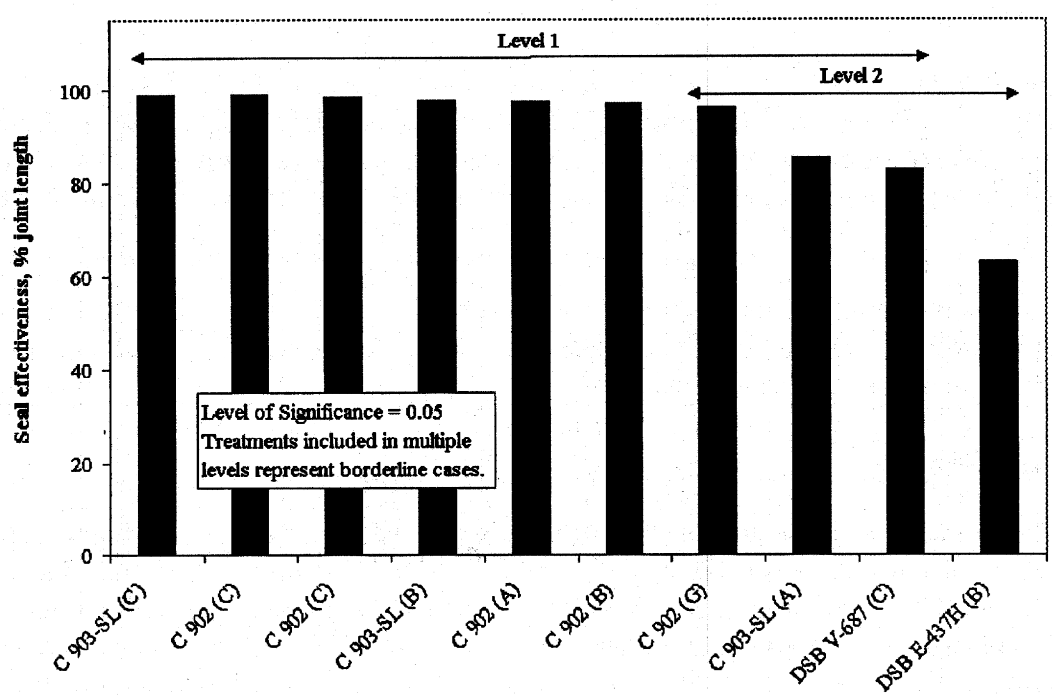

Figure 37. Overall effectiveness groupings for Campo, Colorado transverse joint seal treatments.

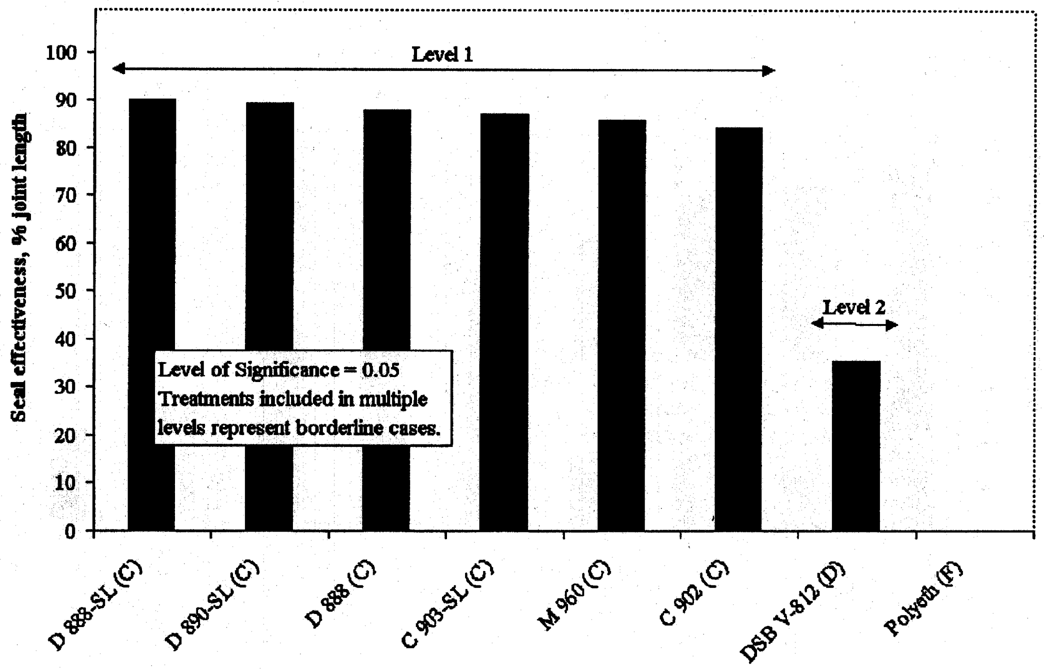

Figure 38. Overall effectiveness groupings for Wells, Nevada transverse joint seal treatments.

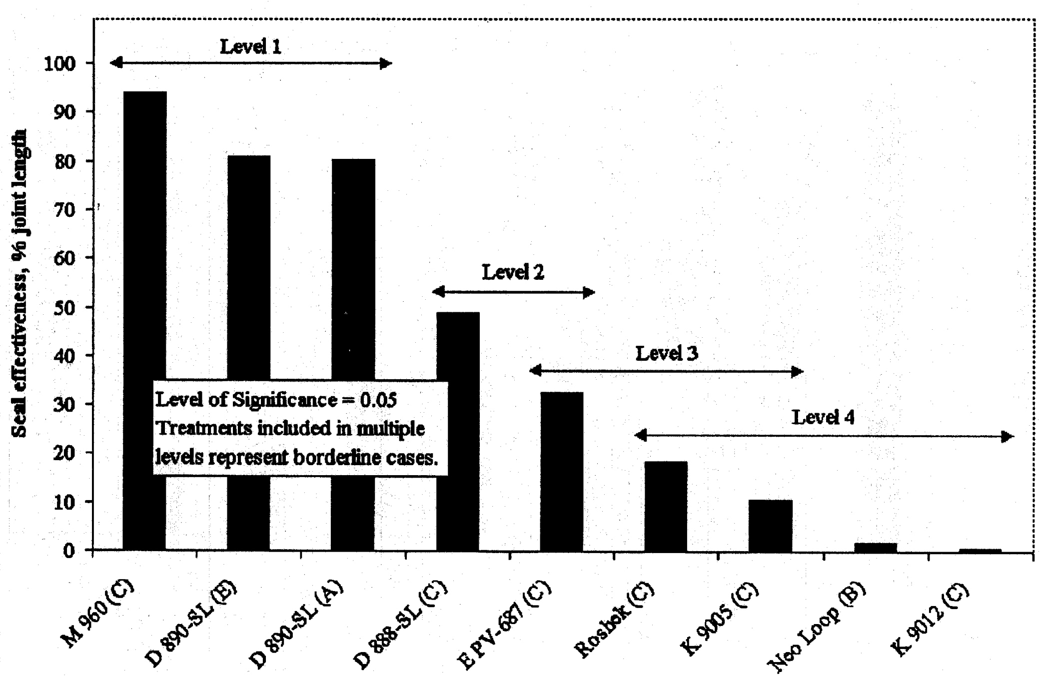

Figure 39. Overall effectiveness groupings for Tremonton, Utah transverse joint seal treatments.

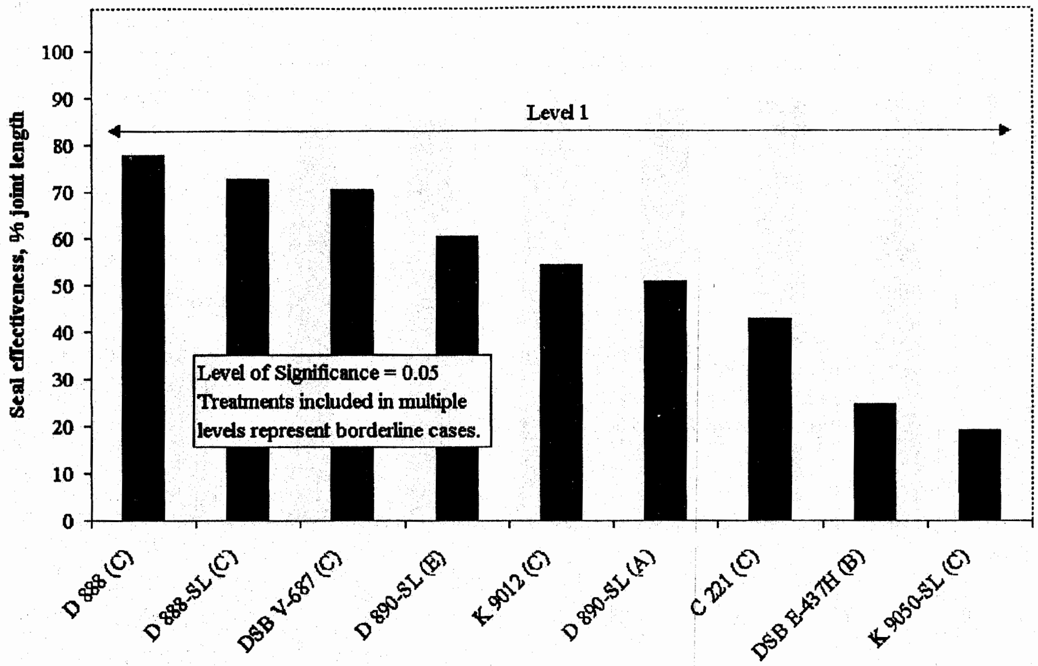

Figure 40. Overall effectiveness groupings for Salt Lake City, Utah transverse joint seal treatments.

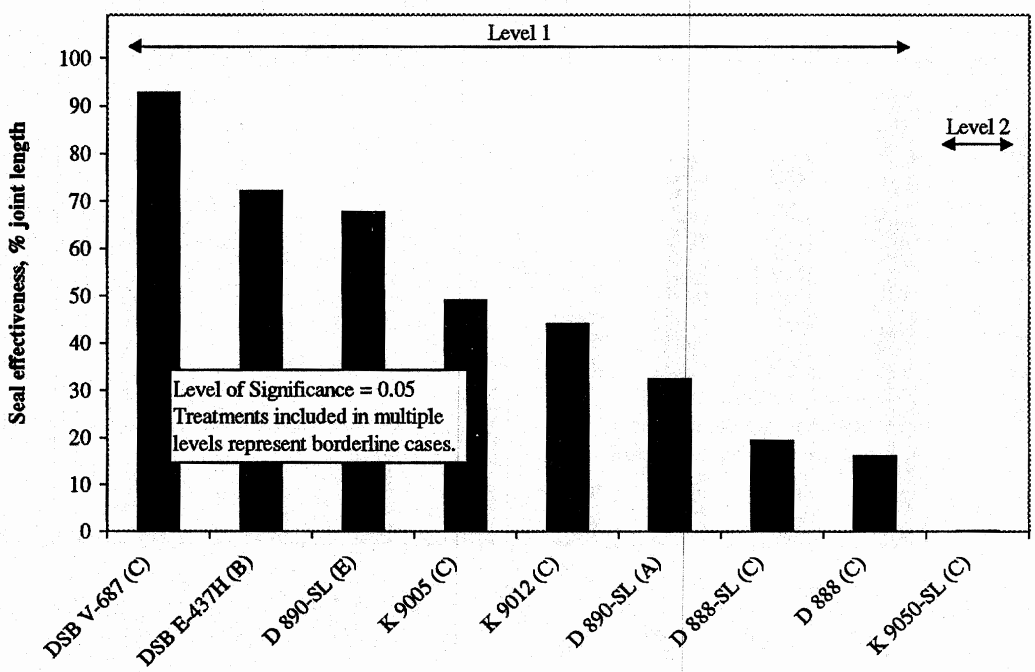

Figure 41. Overall effectiveness groupings for Heber City, Utah transverse joint seal treatments.

- In general, insufficient failure has occurred in the silicone treatments in order to find any statistical differences at this time. However, marginally poorer performance has been identified in the Crafco 902 seals placed in 9-mm-wide beveled joints and the Crafco 903-SL seals placed in 6-mm-wide joints. The former treatment was placed too thin in several joints (mean shape factor of 0.32 in one section), resulting in some cohesive failure. The latter treatment was placed too high in many locations, which exposed the seal to contact with traffic and has resulted in considerable adhesion failure.

Wells, Nevada

- Silicone seal treatments are performing significantly better than the D.S. Brown compression seal at this site. However, full-depth spalling has resulted in considerable overall failure (between 10 and 16 percent) in each treatment.

- Though some of the silicone seal treatments were found to have been installed with very low shape factors (<0.4), no statistical differences in current performance exist.

- At 0 percent effectiveness, the 18-year-old polyethylene sealant (all other seals are approximately 6 years old) represents the lowest category of current performance. All of its failures have been in the form of full-depth cohesion loss.

Tremonton, Utah

- With the exception of Dow 888-SL placed in 9-mm joints, silicone seal treatments are performing statistically better than the compression seals, hot-applied seals, and the Roshek seal. Although the two Dow 890-SL joint seal treatments are currently performing statistically the same as the Mobay 960 treatment, the fact that these treatments were occasionally placed high or thin in the joint has caused them to incur considerably more failure than the Mobay 960 seals.

- The low performance levels of the Esco PV-687 and Kold Seal Neo Loop compression seals are largely attributable to improper installation and poor design, respectively. Esco PV-687 seals were installed by hand rather than machine, and the unique design of the Kold Seal Neo Loop appears to foster gap failure.

- Full-depth adhesion loss is the primary reason for the two hot-applied seals (Koch 9005 and Koch 9012) falling in the lowest performance category at this site. Both seals were reported as being somewhat or very hard during the 1997-1998 field inspection, which may have led to the development of adhesion failure. As discussed in chapter 2, there was some difficulty in maintaining the proper application temperature of the Koch 9012 sealant during installation.

Salt Lake City, Utah

- Despite the fact that some treatments have experienced much greater amounts of failure than others, the results of Tukey groupings do not indicate a significant difference in current overall performance between any of the various treatments. Nevertheless, the following points should be made with regard to the performance characteristics of some of the joint seal treatments:

- Two Dow 890-SL treatments showed considerably lower effectiveness levels than the Dow 888 and Dow 888-SL treatments. These lower effectiveness levels were partly the result of the seals being placed too high in the joint, leading to contact with traffic and, consequently, full-depth adhesion loss.

- The performance of the Koch 9012 seals may have been affected by contamination of the material during installation.

- High shape factors (>1.40) may have contributed to the very poor performance of the Crafco RS 221 seals.

<u>Heber City, Utah</u>

- Tukey groupings indicate that all treatments, except Koch 9050-SL polysulfide, are statistically performing the same at this site. However, as seen in figure 41, there is a wide range in the effectiveness levels of the various treatments. It is believed that the variability in performance between replicate sections is the reason for no overall statistical differences among eight of the nine treatments. Recall from table 3 (chapter 2) that the joints in the eastbound lane test sections received much higher waterblasting and airblasting pressures than the joints in the westbound lane test sections. Other factors in the performance of some of these sealants are as follows:

  - About half of the D.S. Brown E-437H seals were installed by hand, which may account for some of the failure of this treatment.

  - Difficulty in placing the two Dow 890-SL seals in 3-mm joints could be a factor in the poor performance of these seals.

  - Placement of seals too high in the joint could be a factor for some of the treatments, particularly Dow 890-SL in 3-mm-wide joints, Koch 9012, Koch 9005, and D.S. Brown V-687.

- Mass adhesive and cohesive failures have led to the total failure of the Koch 9050-SL polysulfide seals. This material was found to be very hard during the 1997-1998 field inspection, and it showed poor resilience.

<u>General</u>

- Neoprene compression seals installed by hand have shown poorer performance than expected.

- Among 3-mm-wide joints formed using Soff-Cut equipment and wet-sawing equipment, and sealed with Dow 890-SL, no significant differences have been individually identified at the Tremonton, Salt Lake City, and Heber City sites.

- No statistical differences in current performance have been identified among Crafco 903-SL, Dow 888, Dow 888-SL, and Dow 890-SL seals placed in 9-mm-wide joints at either Mesa or Wells.

Longitudinal Joint Seals

The results of the Tukey comparisons of current (1997-1998) longitudinal joint seal effectiveness are illustrated in figures 42 and 43. Noteworthy observations regarding the performance groupings of these seals at the Mesa and Wells sites are given below.

Mesa, Arizona

- Generally speaking, the performance patterns of the longitudinal joint seals at Mesa mirror those of the transverse joint seals. No statistical differences in current performance were found, even though two hot-applied joint seal treatments (Crafco SS 444 and Crafco RS 221) showed substantial levels of failure. As with the transverse joint seals, extended heating and overheating of the Crafco SS 444 sealant (in one replicate) are likely to have attributed to this material's current poor performance.

Wells, Nevada

- Like the transverse joint seals at Wells, the statistical performance breakout of longitudinal joint seals at this site show the D.S. Brown V-812 compression seals with distinctly lower performance than all silicone seals. Full-depth spalling has also been the cause for considerable overall failure in the silicone treatments.

Analysis of Variance of Service Life

A second way in which the performance of experimental seals was evaluated was through analysis of variance of joint seal service life. The service life of a particular seal type provides a better overall picture of performance because it indicates the seal's effectiveness over time and, more importantly, its longevity in maintaining a minimum acceptable level of effectiveness.

To conduct a service life analysis, it was first necessary to define a minimum acceptable effectiveness level. Because of the highly varying levels of failure observed throughout the SPS-4 test sites, a value of 75 percent effectiveness was chosen for this analysis. Figure 44 illustrates the service life determination concept. In this figure, a particular joint seal treatment has exhibited varying losses in effectiveness over time. After 54 months, the treatment maintained an 88 percent effectiveness rating. However, after 66 months, the treatment dropped to a 69 percent effectiveness rating. At the level of 75 percent effectiveness, the corresponding estimated age (i.e., service life) is 62 months.

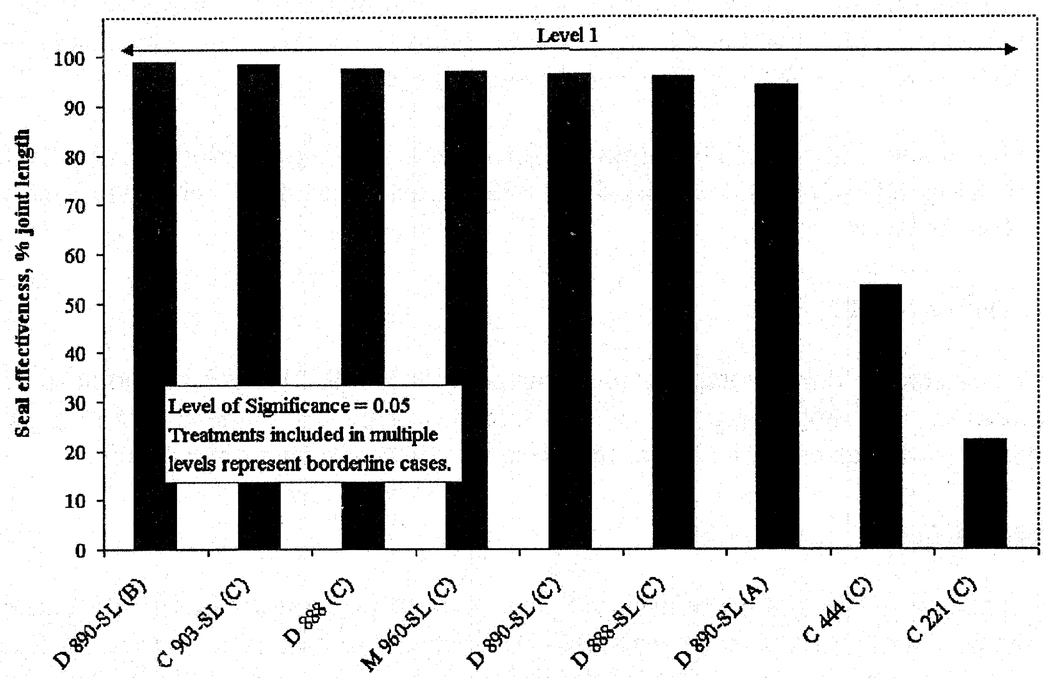

Figure 42. Overall effectiveness groupings for Mesa, Arizona longitudinal joint seal treatments.

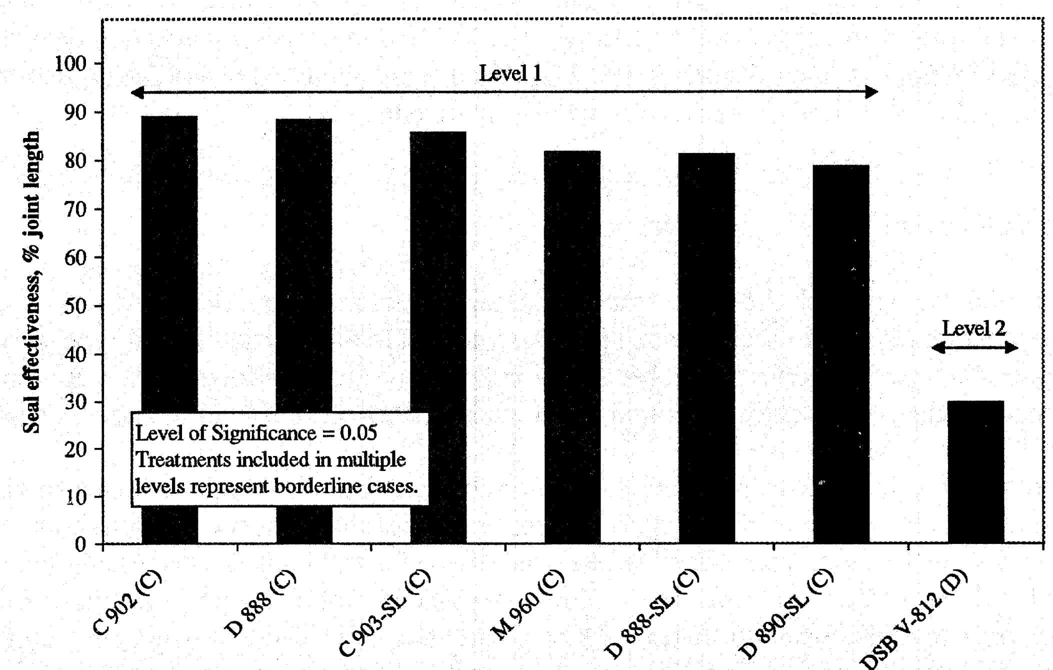

Figure 43. Overall effectiveness groupings for Wells, Nevada longitudinal joint seal treatments.

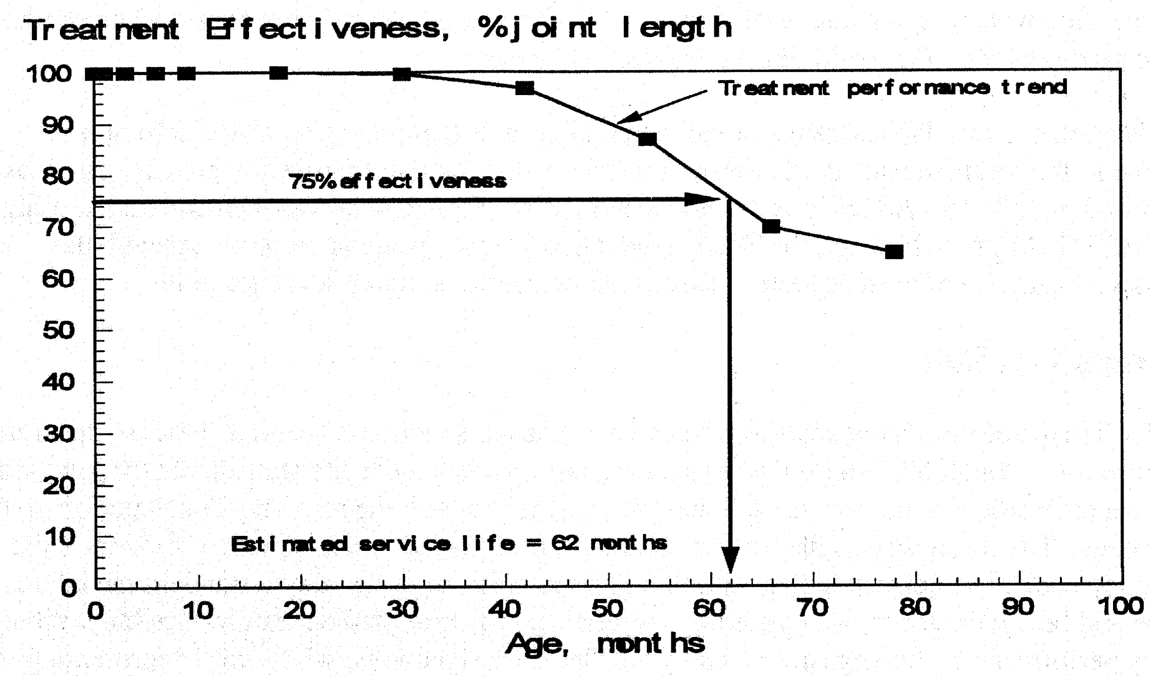

Figure 44. Illustration of service life estimation, based on 75 percent effectiveness.

For the analyses conducted in this study, the estimated service lives of individual joint seals were determined, and then the mean and standard deviation values of service life were computed for each joint seal treatment. This approach allowed for the consideration of the variation that exists in treatment performance from joint to joint.

Based on the appearances of the time-series performance data for many individual sealed joints, third-order polynomial regression was chosen to provide best-fit curves to each set of data. The form of a third-order polynomial regression equation is as follows:

$$\%Eff = a_0 + a_1 \times Age + a_2 \times Age^2 + a_3 \times Age^3 \quad \text{(Eq. 3)}$$

where: $\%Eff$ = Seal effectiveness, percent.
a_0, a_1, a_2, a_3 = Regression coefficients.
Age = Seal age, months.

Following the completion of each regression, which was performed using the SAS® Regression (REG) procedure, the resulting *a* coefficient values were inserted into equation 3 and the *Age* term was solved for using the 75 percent effectiveness criterion (i.e., $\%Eff = 75$). The resulting *Age* value represented the service life of a particular joint seal treatment applied to an individual joint. In many instances, the resulting *Age* value was equal to or less than the time period spent evaluating the joint seal. In other words, an individual joint seal had reached 75 percent effectiveness by its final evaluation, and so the computed *Age* value represented an estimate of the actual life. In other instances, however, an individual joint seal had not reached 75 percent effectiveness by its final evaluation, and the computed *Age* value represented an estimate of the predicted life. Figure 45 illustrates these two cases.

Using the service life estimates of individual joint seals comprising a particular joint seal treatment, the mean and standard deviation of service life for that treatment were calculated, as illustrated in table 18. An analysis of variance of the service life data was then conducted using the SAS® GLM procedure and the Tukey studentized range grouping method. As with the analysis of variance of current performance, a 95 percent confidence level was used.

Transverse Joint Seals

The results of the Tukey analysis of estimated transverse joint seal service lives are illustrated in figures 46 through 50. These figures show the estimated service life statistics of the joint seal treatments installed at the various test sites, in conjunction with the resulting Tukey performance groupings. The mean service life of each treatment is displayed and is represented by the solid square symbol. The corresponding variation in service life, in terms of one standard deviation above and below the mean, is depicted by the vertical line through the mean service life symbol. Tukey performance groupings are given by the "level" designations, with level 1 representing the highest performance, followed by level 2, level 3, and so on. Because of the very high levels of effectiveness among the treatments at Campo and because of the short performance period there (2 years), it was determined that a service life analysis of the Campo treatments was premature.

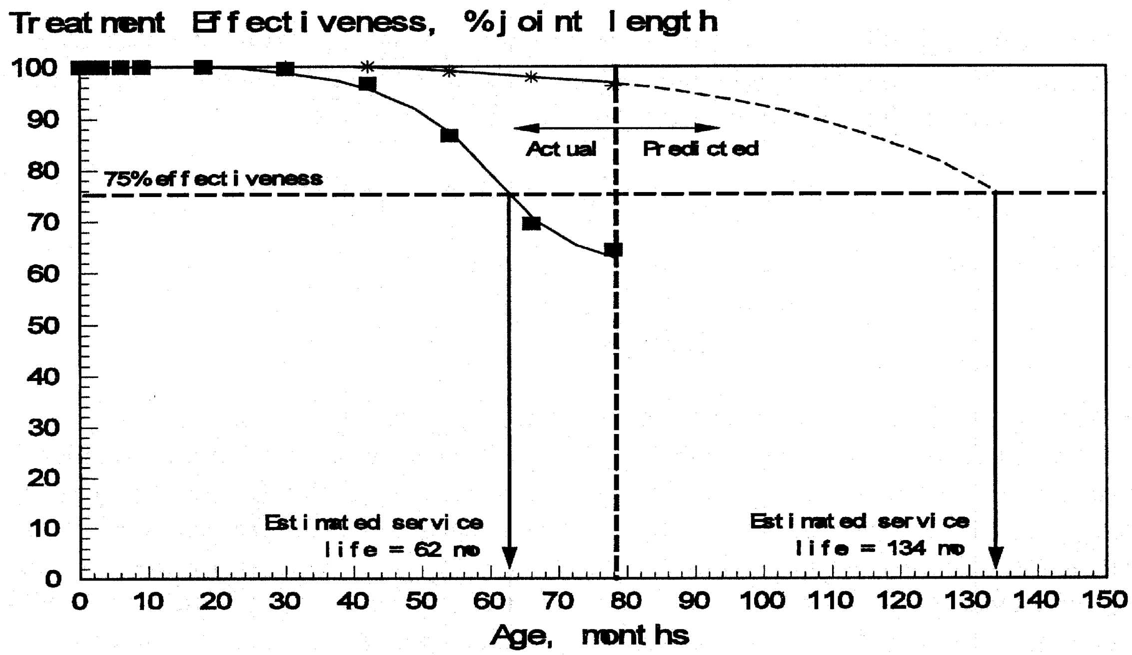

Figure 45. Illustration depicting estimates of actual and predicted service lives.

Table 18. Illustration of service life statistics computation.

Replicate-Joint No.	Estimated Service Life, months	Replicate-Joint No.	Estimated Service Life, months
1-2	64.3	2-2	66.9
1-5	64.0	2-5	62.2
1-8	59.9	2-8	63.8
1-10	56.7	2-10	65.1
1-11	50.7	2-11	58.3
1-13	61.2	2-13	69.4
1-16	58.8	2-16	63.6
1-18	74.2	2-18	60.4
1-22	64.7	2-22	57.5
1-23	70.1	2-23	64.3
1-27	67.7	2-27	66.7
1-29	59.3	2-29	70.3
Mean = 63.3 Standard Deviation = 5.22			

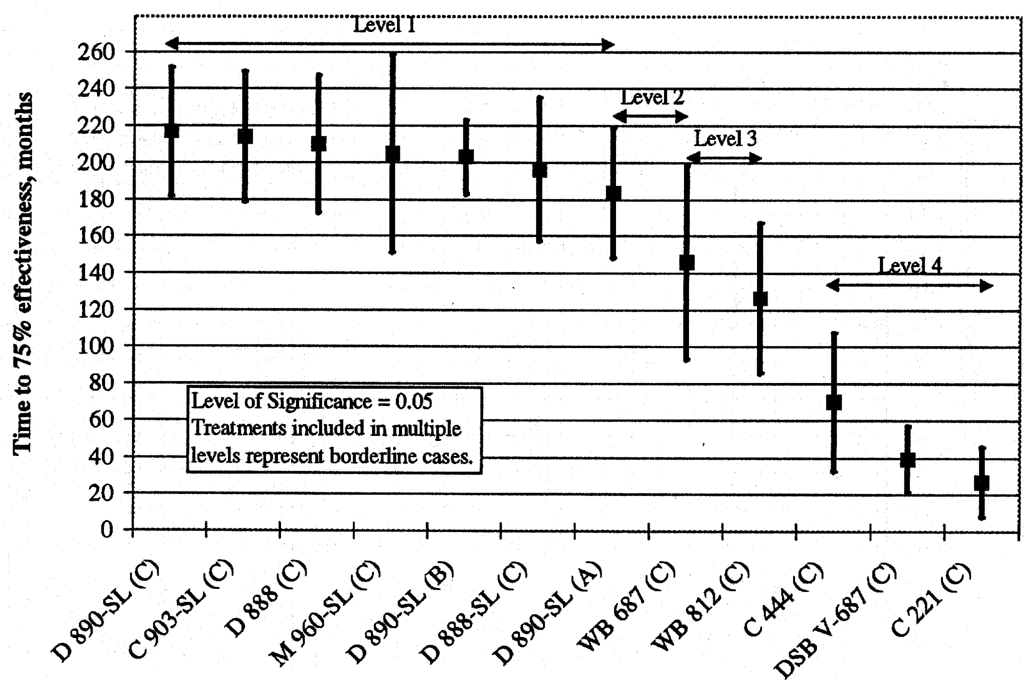

Figure 46. Tukey analysis of estimated transverse joint seal service lives at Mesa, Arizona test site.

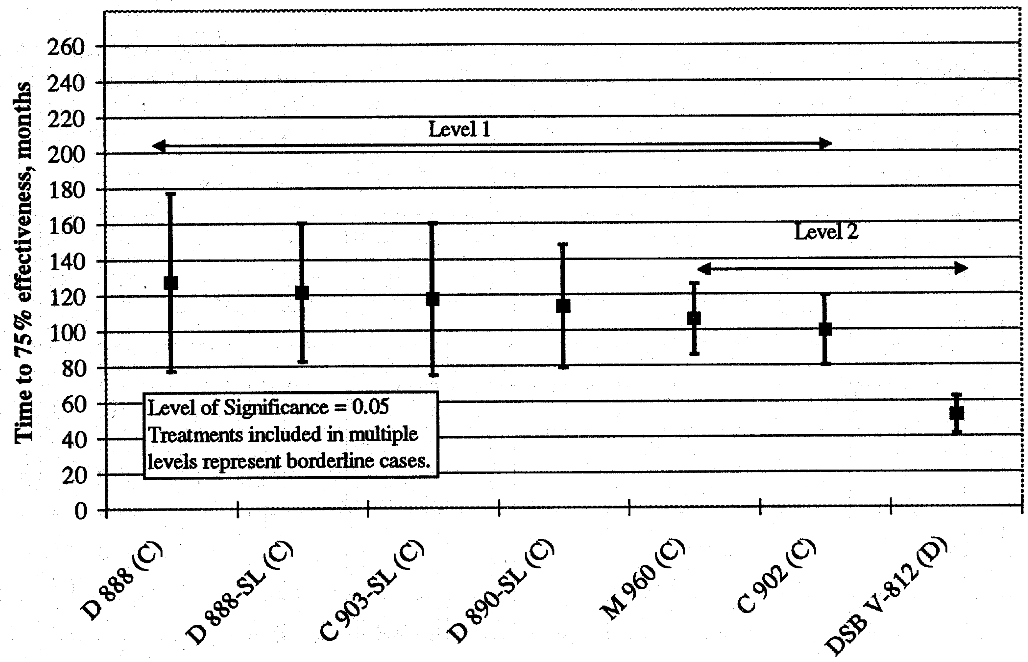

Figure 47. Tukey analysis of estimated transverse joint seal service lives at Wells, Nevada test site.

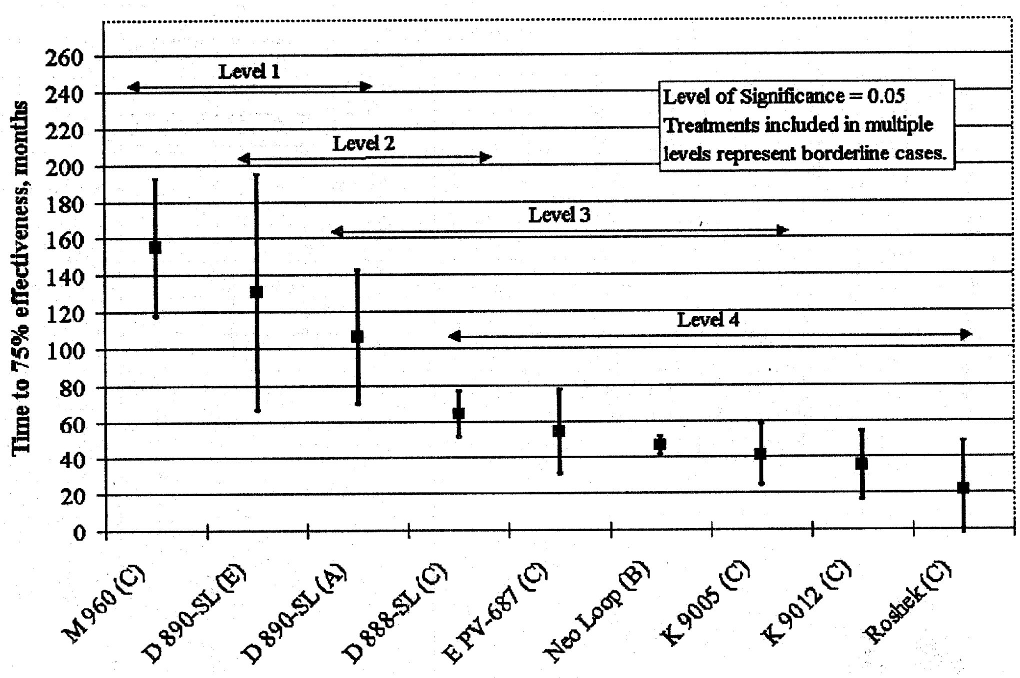

Figure 48. Tukey analysis of estimated transverse joint seal service lives at Tremonton, Utah test site.

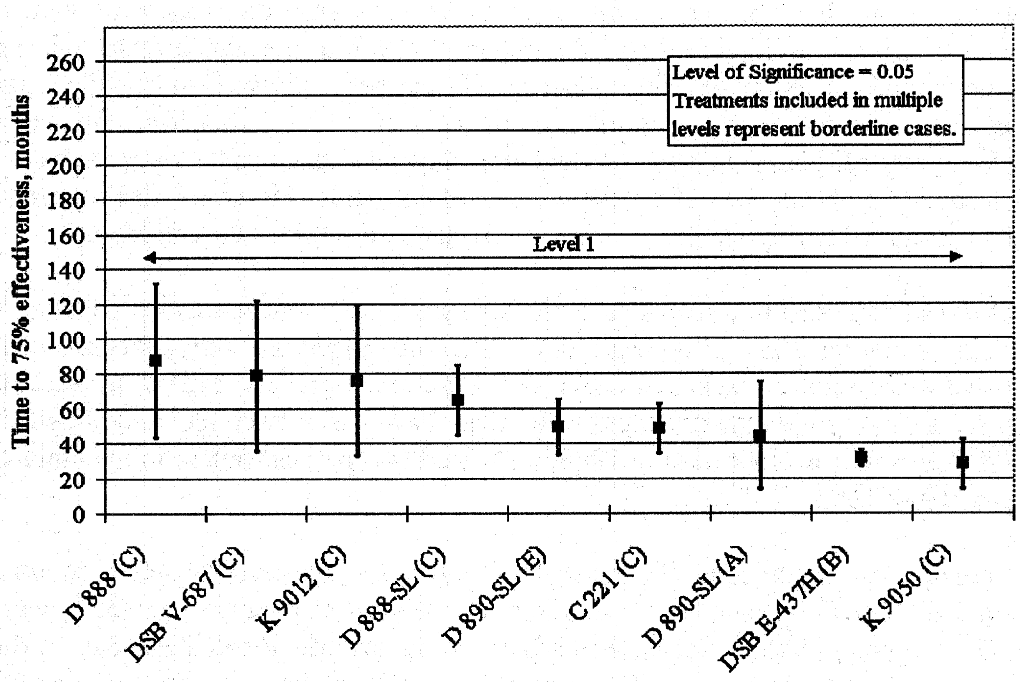

Figure 49. Tukey analysis of estimated transverse joint seal service lives at Salt Lake City, Utah test site.

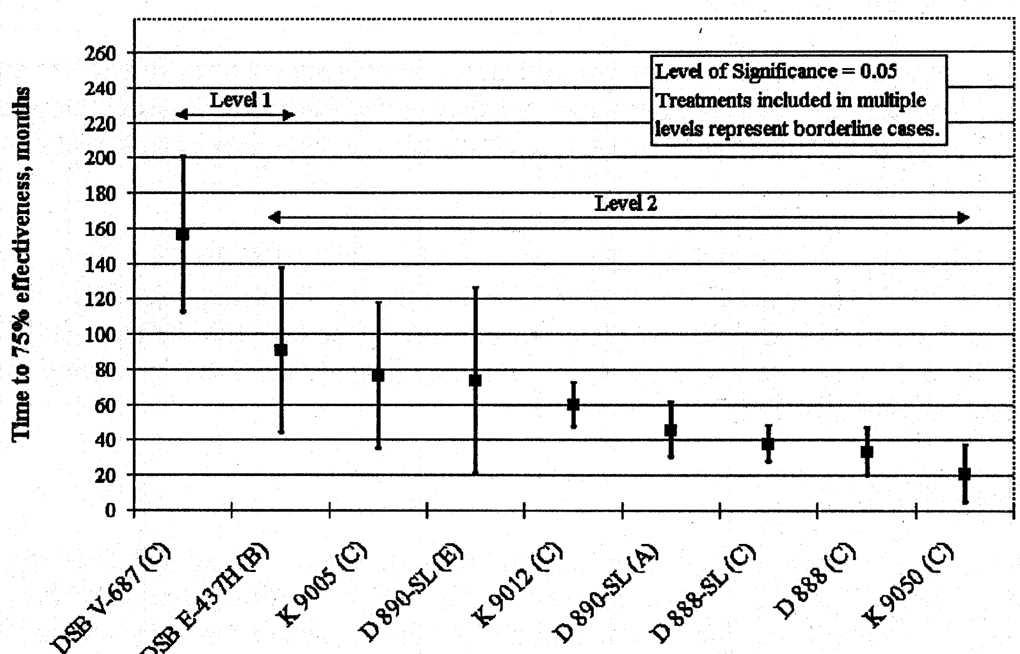

Figure 50. Tukey analysis of estimated transverse joint seal service lives at Heber City, Utah test site.

In general, the Tukey service life groupings reinforce the observations made previously regarding current performance groupings. For instance, at Mesa, the standard silicone seal treatment and five of the six self-leveling silicone seal treatments showed statistically longer service lives than the compression seals and hot-applied seals. The sixth self-leveling silicone seal treatment, Dow 890-SL placed in 3-mm-wide joints, showed a statistically longer service life than the two hot-applied seals and two of the three compression seals. However, this material showed a marginally shorter service life in 3-mm-wide joints than in 6- and 9-mm-wide joints.

Most of the silicone seal treatments at Wells have statistically outperformed the compression seal at that site. Only the Mobay 960 and Crafco 902 seals placed in 9-mm joints showed the same statistical service life as the D.S. Brown V-812 compression seal. Due to the lack of pre-1991 performance data on the polyethylene seal, no estimates of service life could be made for this material. Though it was installed in 1980, it showed 100 percent failure in the initial field inspections of 1994-1995.

At Tremonton, two of the four silicone seals—Mobay 960 in 9-mm-wide conventionally sawed joints and Dow 890-SL in 3-mm-wide Soff-Cut joints—statistically showed longer service lives than the compression seals, hot-applied seals, and the proprietary Roshek seal. A third silicone seal, Dow 890-SL in 3-mm-wide conventionally sawed joints, statistically showed the same estimated service life as the two compression seals and the hot-applied rubberized asphalt product, Koch 9005. The fourth silicone seal, Dow 888-SL, placed in 9-mm-wide conventionally sawed joints, shows no statistical difference in estimated service life when compared to the two compression seals, the two hot-applied seals, and the Roshek seal. Lastly, no statistical differences in estimated service life were found between the Dow 890-SL 3-mm-wide Soff-Cut and conventionally sawed joints, which suggests that the more expeditious Soff-Cut sawing method could be more cost-effective.

As with the results of the Tukey analysis of current performance, no statistical distinctions in estimated service life were found among the treatments at the Salt Lake City site. However, it can again be pointed out that a more cost-effective sawing method than conventional sawcutting is the Soff-Cut method.

At the Heber City site, the D.S. Brown V-687 compression seal showed a statistically longer service life than the silicone seals, hot-applied seals, and the self-leveling polysulfide seal. Moreover, with no statistical differences in estimated service life between the Dow 890-SL 3-mm-wide Soff-Cut and conventionally sawed joints, the more expeditious Soff-Cut sawing method may be economically justifiable.

Longitudinal Joint Seals

The results of the Tukey analysis of estimated longitudinal joint seal service lives are illustrated in figures 51 and 52. The only statistical distinction in estimated service life at Mesa was between the Crafco RS 221 joint seal treatment (significantly lower service life) and four of the seven silicone seal treatments. Recall that no distinctions were apparent in the evaluation of current performance levels.

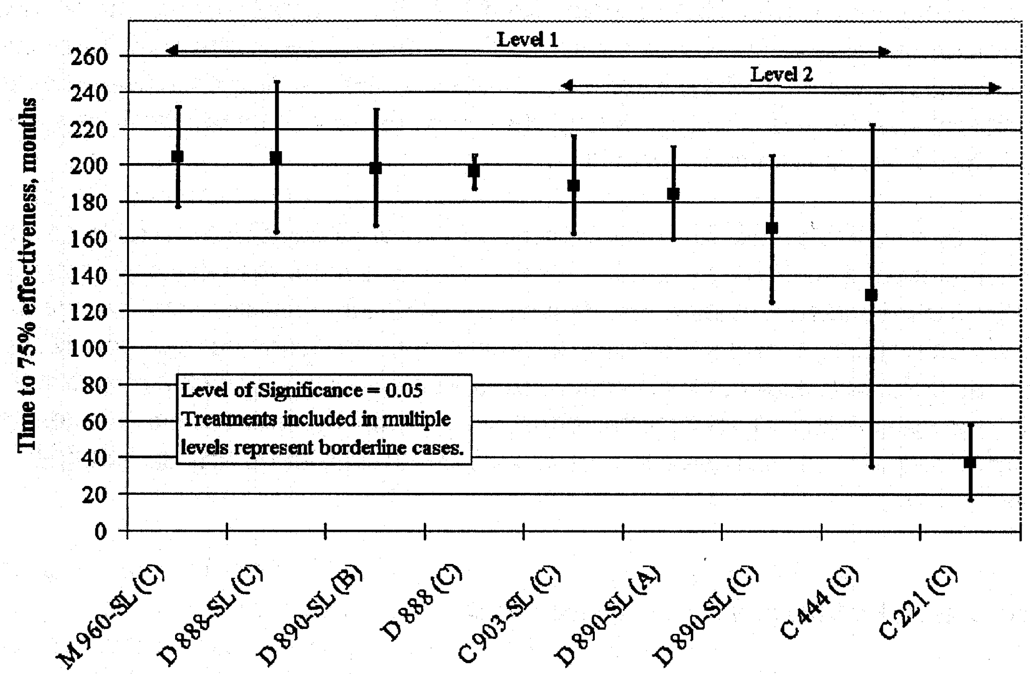

Figure 51. Tukey analysis of estimated longitudinal joint seal service lives at Mesa, Arizona test site.

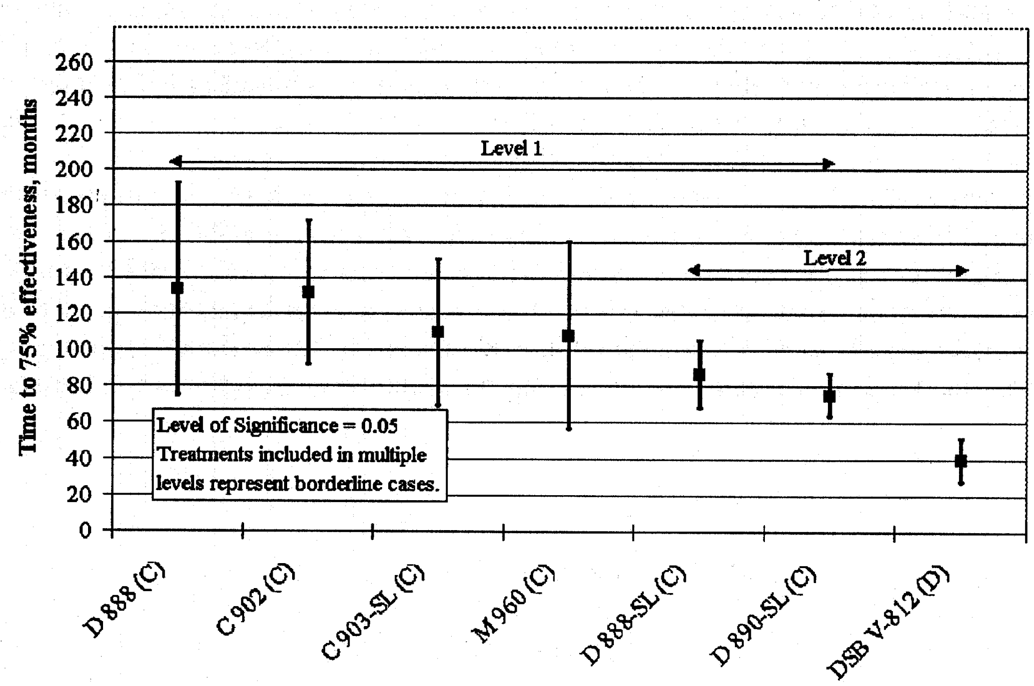

Figure 52. Tukey analysis of estimated longitudinal joint seal service lives at Wells, Nevada test site.

Among the longitudinal joint seal treatments at Wells, it was found that the D.S. Brown V-812 compression seal treatment showed a statistically shorter service life than the three standard silicone treatments installed at that site and one of the three self-leveling silicone treatments. This compression seal showed statistically poorer performance than its counterparts during the 1997-1998 field inspections.

Finally, in figures 46 through 52, it can be seen that some of the joint seal treatments had high standard deviations of estimated service life. Probable factors in these high standard deviations include differences in material quality, sealing workmanship, and joint characteristics (e.g., width and condition, movement) between replicate sections of a given treatment. A good example of this is the Crafco SS 444 placed at the Mesa, Arizona test site. As seen in tables C-2 and C-50 in appendix C, the effectiveness levels over time for the replicate 1 seals were much lower than for the replicate 2 seals, due to the extended heating that occurred with this material during installation.

Laboratory Test—Field Performance Assessments

Because no statistical distinctions in estimated service life were found among the three non-self-leveling silicones (Dow 888, Mobay 960, and Crafco 902) placed in 9-mm-wide joints at Wells, and because each sealant met the established laboratory test specifications, a clear performance indicator could not be identified. However, the excellent performance of these three sealants at Wells reflects well upon the set of tests conducted (e.g., tensile stress at 150 percent strain, bond to PCC mortar, movement capability and adhesion) and the established test criteria.

With no statistical differences in estimated service life observed among the three self-leveling silicones (Crafco 903-SL, Dow 888-SL, and Dow 890-SL) placed in 9-mm-wide joints at Wells, no evidence could be found that one or more laboratory tests provides clear indications of performance.

Though three of the four self-leveling silicone sealants placed at Mesa did not entirely satisfy the established laboratory test specifications—Crafco 903-SL and Dow 890-SL failed the durometer hardness requirement and Mobay 960-SL failed the movement capability and adhesion requirement—the effect on performance (9-mm-wide joints) has not been apparent. All four sealants, including the Dow 888-SL sealant that met the specifications, showed statistically similar service lives, and the limited failure observed in each sealant has been in the form of full-depth spalling.

CHAPTER 6. SUMMARY OF FINDINGS AND RECOMMENDATIONS

The SHRP SPS-4 supplemental joint seal experiment represents the interests and desires of selected State highway agencies in determining the most effective and long-lasting materials and methods for sealing joints in their jointed concrete pavements. Six test sites were constructed in four States for this purpose, with each test site containing between 8 and 12 installed combinations of sealant material and joint preparation procedure. Well over 2,000 transverse joints were sealed and performance was monitored as part of the study, and many longitudinal joints were also sealed and evaluated.

The details of the test sites constructed as part of the SHRP SPS-4 supplemental joint seal study were provided in chapters 1 and 2 of this report. An in-depth discussion of the results of laboratory tests performed on some of the experimental materials was provided in chapter 3. Complete documentation of the field performance information collected in the study was given in chapter 4, and the results of various data analyses designed to distinguish treatment performance and cost-effectiveness were presented in chapter 5.

This chapter summarizes the major findings and observations of the SPS-4 supplemental joint seal study. The findings are divided into general findings and specific findings about materials and methods. Also contained in this chapter are various recommendations concerning joint sealing operations that could be useful to highway construction and maintenance administrators, practitioners, and researchers.

Findings

General

- At the conclusion of the 1997-1998 field inspections, a significant amount of overall joint seal failure had developed at five of the six SPS-4 supplemental joint seal sites. The overall average failure of treatments at these 5- to 7-year-old sites ranged from 19 to 58 percent of the joint length. At the sixth site, overall joint seal failure was low (approximately 9 percent) because of the young age (2 years) of the treatments.

- Of 56 joint seal treatments placed at the 6 sites, 26 have shown favorable performance (≥80 percent effectiveness), 7 have shown mediocre performance (65 to 79.9 percent effectiveness), 1 has shown poor performance (50 to 64.4 percent effectiveness), and 22 have reached "failed" status (<50 percent effectiveness).

- Joint seal treatments with the longest mean estimated service life at each site were as follows:

  - Mesa (transverse seals): Dow 890-SL in 9-mm-wide joints (218 months).
  - Mesa (longitudinal seals): Mobay 960-SL in 9-mm-wide joints (204 months).
  - Wells (transverse seals): Dow 888 in 9-mm-wide joints (127 months).
  - Wells (longitudinal seals): Dow 888 in 9-mm-wide joints (134 months).
  - Tremonton (transverse seals): Mobay 960 in 9-mm-wide joints (155 months).
  - Salt Lake City (transverse seals): Dow 888 in 9-mm-wide joints (88 months).
  - Heber City (transverse seals): D.S. Brown V-687 in 9-mm-wide joints (158 months).

- Poor construction practices, such as overheating and extended heating of hot-applied sealants, placement of silicone seals too thin or too high in the joint, and hand installation of compression seals, have affected the performance of several joint seal treatments.

- Despite large variations in performance among the transverse joint seal treatments at Salt Lake City and Heber City, and the longitudinal joint seal treatments at Mesa, the results of Tukey groupings do not indicate statistical differences in performance among the treatments at each of these sites. A probable explanation of this phenomenon for the Heber City site is that substantially different joint cleaning intensities were used during the installation of replicate sections (i.e., joints in the eastbound test sections received higher waterblast and airblast pressures than joints in the westbound test sections).

- Because of limited laboratory testing and an overall lack of statistical performance differences among sealant materials, no significant relationships were identified between field performance indicators and laboratory-determined material properties.

<u>Materials</u>

Although some of the combinations of material and configuration were installed at multiple sites, the fact that joint cleaning procedures varied from site to site limited the development of broad-based conclusions about the performance of materials. Thus, the findings presented in this section are site-specific.

- Among the seals placed in 9-mm-wide transverse joints at the Mesa site, superior performance has been provided by the one standard silicone (Dow 888) and the four self-leveling silicones (Dow 890-SL, Crafco 903-SL, Mobay 960-SL, and Dow 888-SL). Each had statistically longer estimated service lives than those of competing seals. Two preformed compression seals (Watson Bowman 687 and Watson Bowman 812) at this site showed good performance and, consequently, had statistically longer service lives than the two hot-applied seals (Crafco SS 444, which incurred substantial cohesion failure as a result of extended heating or overheating during installation, and Crafco RS 221) and a third compression seal (D.S. Brown V-687).

- Three of the five silicone seals (Dow 888, Mobay 960-SL, and Dow 888-SL) placed in 9-mm-wide longitudinal joints at Mesa showed statistically longer service lives than did the hot-applied rubberized asphalt seal (Crafco RS 221). However, despite considerable cohesive failure in the Crafco SS 444 as a result of extended heating or overheating during installation, all five silicone seals showed statistically the same service lives as Crafco SS 444.

- At the Campo test site, no statistical differences were observed in the 2-year performance levels of the three seals (Crafco 903-SL self-leveling silicone seal, Crafco 902 standard silicone seal, and D.S. Brown V-687 compression seal) placed in 9-mm-wide transverse joints, despite the fact that the compression seal was poorly installed. However, the Crafco 903-SL and Crafco 902 seals placed in 6-mm-wide joints did show statistically longer service lives than that of a second compression seal (D.S. Brown E-437H) that was poorly installed in 6-mm-wide joints.

- No statistical differences in estimated service life were found to exist among the three standard silicone seals (Dow 888, Mobay 960, and Crafco 902) and three self-leveling silicone seals (Dow 888-SL, Crafco 903-SL, and Dow 890-SL) placed in 9-mm-wide transverse joints at the Wells site.

- At the Tremonton site, superior performance was provided by the Mobay 960 standard silicone. The estimated service life of this seal placed in 9-mm-wide joints was statistically longer than the estimated service lives of five similarly placed seals (Dow 888-SL self-leveling silicone, Esco PV-687 preformed compression seal, Koch 9005 hot-applied rubberized asphalt, Koch 9012 hot-applied PVC-coal tar, and Roshek proprietary sealant). Though construction problems are believed to have significantly affected the performance characteristics of the Esco PV-687 and Koch 9012 seals, their estimated service lives were statistically the same as the Dow 888-SL, Koch 9005, and Roshek seals.

- No statistical differences in estimated service life were observed among six different sealants (Dow 888 standard silicone, D.S. Brown V-687 preformed compression seal, Koch 9012 hot-applied PVC-coal tar, Dow 888-SL self-leveling silicone, Crafco RS 221 hot-applied rubberized asphalt, and Koch 9050-SL self-leveling polysulfide) placed in 9-mm-wide transverse joints at the Salt Lake City site. Some of these seals, such as Koch 9012 and Crafco RS 221, were reported to have had construction difficulties.

- At the Heber City site, superior performance was provided by the D.S. Brown V-687 preformed compression seal. The estimated service life of this seal placed in 9-mm-wide joints was statistically longer than the estimated service lives of five similarly placed seals (Koch 9005 hot-applied rubberized asphalt, Koch 9012 hot-applied PVC-coal tar, Dow 888-SL self-leveling silicone, Dow 888 standard silicone, and Koch 9050-SL self-leveling polysulfide).

Configurations

- At the Mesa site, no statistical differences in estimated service life were observed among the 3-, 6-, and 9-mm-wide transverse joints sealed with Dow 890-SL self-leveling silicone. Likewise, no statistical differences in estimated service life were observed among the 3-, 6-, and 9-mm-wide longitudinal joints sealed with Dow 890-SL self-leveling silicone.

- At the Campo site, no statistical differences in the 2-year performance levels were observed among the 3-, 6-, and 9-mm-wide transverse joints sealed with Crafco 903-SL self-leveling silicone. In addition, no statistical differences in the 2-year performance levels were observed among the 3-, 6-, 9-mm, and beveled 9-mm-wide transverse joints sealed with Crafco 902 standard silicone.

- At the Tremonton site, no statistical differences in estimated service life were observed among the 3-mm Soff-Cut-sawed and conventionally sawed transverse joints sealed with Dow 890-SL self-leveling silicone.

- No statistical differences in estimated service life were observed among the 3-mm Soff-Cut-sawed and conventionally sawed transverse joints sealed with Dow 890-SL at the Salt Lake City site.

- Like the Tremonton and Salt Lake City sites, no statistical differences in estimated service life were observed among the 3-mm Soff-Cut-sawed and conventionally sawed transverse joints sealed with Dow 890-SL at the Heber City site.

Recommendations

Recommendations are provided below for both the designer/operator of joint sealing projects and the planner/researcher for joint sealing policies.

Joint Sealing Operations

All joint sealing recommendations are based on available performance data and on experience with test site installation.

- Long-term (>8 years) initial joint seal performance can generally be obtained using standard and self-leveling silicone materials (e.g., Dow 888, Mobay 960, Crafco 902, Dow 890-SL, Mobay 960-SL, and Crafco 903-SL) properly placed in thoroughly cleaned 9-mm-wide joints.

- Long-term performance similar to the standard and self-leveling silicone seal types can also be achieved using Dow 890-SL properly placed in thoroughly cleaned 3- or 6-mm-wide joints. Since less material is required for these narrower joints, these seals may be more cost-effective.

- Similar long-term performance capabilities achieved by Dow 890-SL placed in 3-mm conventionally sawed and Soff-Cut-sawed joints suggest that the more expeditious Soff-Cut method would be more cost-effective than the conventional sawing method.

- Although long-term initial joint seal performance is obtainable with preformed compression seals, such as Watson Bowman 687 and D.S. Brown V-687, proper joint design and seal installation are critical.

- Hot-applied sealants (e.g., Crafco RS 221, Koch 9012) placed in 9-mm-wide joints are likely to provide moderate performance (4 to 8 years) if they are properly heated and are installed in thoroughly cleaned joints. Though their service lives appear to be substantially shorter than silicone seals and compression seals, their installation costs are considerably less, which may make them the most cost-effective option.

<u>Education and Research</u>

The SHRP SPS-4 supplemental joint seal study has taken steps toward improving the state of the practice of sealing joints in concrete pavements. Recommendations for actions in research and education that may lead to further progress in joint resealing are as follows:

- Continue monitoring the SPS-4 supplemental joint seal test sites. The Mesa, Wells, and Campo sites, in particular, have many joint seal treatments with less than 25 percent overall failure. Most of the treatments with less than 25 percent overall failure are standard and self-leveling silicones. Additional time-series effectiveness data will likely enable further distinctions to be made regarding the performance of these materials and some of the preformed compression seals.

- Promote the design and construction of additional joint seal test sites. Because many new advancements in materials and equipment have occurred since the installations of the six SPS-4 supplemental joint seal test sites, it is highly recommended that agencies conduct their own customized joint seal experiments. The materials and methods commonly used by agency crews should be evaluated against the various materials and methods shown to be effective in the SPS-4 supplemental joint seal study. New or promising technologies should be included in the experiments.

- Transfer the technology. The information gathered under the SPS-4 supplemental joint seal experiment can be put to its best use when it reaches the most people on the decision-making, supervisory, and installation levels of joint sealing operations. Therefore, continued incorporation of this study's results into technology transfer programs is essential.

REFERENCES

Ambroz, J.K. and L.D. Evans. 1996. *Construction Report for Campo, Colorado SHRP SPS-4 Experiment 08A400*, Federal Highway Administration (FHWA) Contract No. DTFH61-93-R-00051, FHWA, McLean, Virginia.

Evans, L.D., C.A. Good Mojab, A.J. Patel, A.R. Romine, K.L. Smith, and T.P. Wilson. 1992. *SHRP H-106 Evaluation and Analysis Plan (EAP)*, SHRP Contract No. SHRP-89-H-106, SHRP, National Research Council, Washington, D.C.

Evans, L.D., M.A. Pozsgay, K.L. Smith, and A.R. Romine. 1999. *LTPP Pavement Maintenance Materials: SHRP Joint Reseal Experiment, Final Report*, Federal Highway Administration, Washington, D.C.

Evans, L.D. and C.J. Wienrank. 1995a. *Draft Construction Report for Wells, Nevada SHRP SPS-4 Experiment 32A400*, FHWA Contract No. DTFH61-93-R-00051, FHWA, McLean, Virginia.

Evans, L.D. and C.J. Wienrank. 1995b. *Draft Construction Report for Tremonton, Utah SHRP SPS-4 Experiment 49C400*, FHWA Contract No. DTFH61-93-R-00051, FHWA, McLean, Virginia.

Evans, L.D. and C.J. Wienrank. 1995c. *Draft Construction Report for Salt Lake City, Utah SHRP SPS-4 Experiment 49D400*, FHWA Contract No. DTFH61-93-R-00051, FHWA, McLean, Virginia.

Evans, L.D. and C.J. Wienrank. 1995d. *Draft Construction Report for Heber City, Utah SHRP SPS-4 Experiment 49E400*, FHWA Contract No. DTFH61-93-R-00051, FHWA, McLean, Virginia.

Meier, W.R. and E.J. Elnicky. 1992. *Construction Report for Arizona's SHRP SPS-4 Experiment*, Report No. AZ92-377-1, Arizona Department of Transportation, Phoenix, Arizona.

U.S. Department of Commerce. 1983. *Climatic Atlas of the United States*. U.S. Dept. of Commerce, Environmental Science Services Administration.

APPENDIX A. TEST SITE LAYOUTS

The SHRP SPS-4 supplemental joint seal test sites were laid out in two replicates. These replicates were established in adjacent, opposing lanes at the three Utah sites. However, at the Mesa, Arizona; Campo, Colorado; and Wells, Nevada test sites, the replicates were placed end-to-end. The order of sealant placement at each test site was chosen randomly. Tables A-1 through A-6 list the combinations of sealant material and joint configuration used at each site in the order that they lie along the roadway.

Table A-1. Layout of test sections at the Mesa, Arizona test site.

Replicate No.	Test Section No. (SHRP ID)	Sealant Material	Joint Configuration
2[a]	13 (04A451)	Dow 890-SL self-leveling silicone	A
	14 (04A452)	D.S. Brown V-687 compression seal	C
	15 (04A453)	Dow 888 non-sag silicone	C
	16 (04A454)	Mobay Baysilone 960-SL self-leveling silicone	C
	17 (04A455)	Unsealed	A
	18 (04A456)	Dow 890-SL self-leveling silicone	C
	19 (04A457)	Dow 888-SL self-leveling silicone	C
	20 (04A458)	Crafco 903-SL self-leveling silicone	C
	21 (04A459)	Crafco RS 221 hot-applied rubberized asphalt	C
	22 (04A460)	Watson Bowman 812 compression seal	C
	23 (04A461)	Crafco SS 444 hot-applied PVC-coal tar	C
	24 (04A462)	Dow 890-SL self-leveling silicone	B
1[b]	01 (04A441)	D.S. Brown V-687 compression seal	C
	02 (04A410)	Crafco 903-SL self-leveling silicone	C
	03 (04A430)	Unsealed	A
	04 (04A442)	Dow 890-SL self-leveling silicone	C
	05 (04A443)	Watson Bowman 687 compression seal	C
	06 (04A444)	Dow 888-SL self-leveling silicone	C
	07 (04A445)	Dow 888 non-sag silicone	C
	08 (04A446)	Crafco SS 444 hot-applied PVC-coal tar	C
	09 (04A447)	Dow 890-SL self-leveling silicone	A
	10 (04A448)	Mobay Baysilone 960-SL self-leveling silicone	C
	11 (04A449)	Crafco RS 221 hot-applied rubberized asphalt	C
	12 (04A450)	Dow 890-SL self-leveling silicone	B

[a] Replicate located in eastbound travel lane. Replicate begins with Section 13 at milepost 16.90 and ends with Section 24 at milepost 17.78.

[b] Replicate located in eastbound travel lane. Replicate begins with Section 1 at milepost 18.15 and ends with Section 12 at milepost 18.90.

Table A-2. Layout of test sections at the Campo, Colorado test site.

Replicate No.	Test Section No. (SHRP ID)	Sealant Material	Joint Configuration
2[a]	10B (08A416)	Crafco RS 902 non-sag silicone	G
	9B (08A455)	Crafco RS 902 non-sag silicone	C
	8B (08A446)	Crafco RS 903-SL self-leveling silicone	C
	7B (08A415)	Crafco RS 902 non-sag silicone	C
	5B (08A445)	Crafco RS 903-SL self-leveling silicone	B
	4B (08A414)	Crafco RS 902 non-sag silicone	B
	3B (08A444)	Crafco RS 903-SL self-leveling silicone	A
	2B (08A413)	Crafco RS 902 non-sag silicone	A
	1B (08A431)	Unsealed	A
1[b]	10A (08A453)	Crafco RS 902 non-sag silicone	G
	9A (08A452)	D.S. Brown V-687 compression seal	C
	8A (08A443)	Crafco RS 903-SL self-leveling silicone	C
	7A (08A412)	Crafco RS 902 non-sag silicone	C
	6A (08A451)	D.S. Brown E-437H compression seal	B
	5A (08A442)	Crafco RS 903-SL self-leveling silicone	B
	4A (08A411)	Crafco RS 902 non-sag silicone	B
	3A (08A441)	Crafco RS 903-SL self-leveling silicone	A
	2A (08A410)	Crafco RS 902 non-sag silicone	A
	1A (08A430)	Unsealed	A

[a] Replicate located in northbound lane. Replicate begins with Section 10B at milepost 3.90 and ends with Section 1B at milepost 4.60.

[b] Replicate located in northbound lane. Replicate begins with Section 10A at milepost 4.66 and ends with Section 1A at milepost 5.30.

Table A-3. Layout of test sections at the Wells, Nevada test site.

Replicate No.	Test Section No. (SHRP ID)	Sealant Material	Joint Configuration
SHRP[a]	1 (323010)	Polyethylene (existing GPS left undisturbed)	F
	2 (32A420)	Dow 888 non-sag silicone (undersealing test section)	C
	3 (32A410)	Dow 888 non-sag silicone	C
	4 (32A430)	Unsealed	C
1[b]	5-1 (32A451)	Dow 890-SL self-leveling silicone	C
	6-1 (32A452)	Crafco RS 903-SL self-leveling silicone	C
	7-1 (32A453)	Dow 888-SL self-leveling silicone	C
	8-1 (32A454)	D.S. Brown V-812 compression seal	D
	9-1 (32A455)	Mobay Baysilone 960 non-sag silicone	C
	10-1 (32A456)	Crafco RS 902 non-sag silicone	C
	11-1 (32A457)	Dow 888 non-sag silicone	C
2[c]	5-2 (32A458)	Dow 890-SL self-leveling silicone	C
	6-2 (32A459)	Crafco RS 903-SL self-leveling silicone	C
	7-2 (32A460)	Dow 888-SL self-leveling silicone	C
	8-2 (32A461)	D.S. Brown V-812 compression seal	D
	9-2 (32A462)	Mobay Baysilone 960 non-sag silicone	C
	10-2 (32A463)	Crafco RS 902 non-sag silicone	C
	11-2 (32A464)	Dow 888 non-sag silicone	C

[a] SHRP replicate located in westbound driving lane. SHRP replicate begins at milepost 348.56 and ends at milepost 348.07.

[b] Replicate located in eastbound lane. Replicate begins with Section 5-1 at milepost 348.06 and ends with Section 11-1 at milepost 348.36.

[c] Replicate located in eastbound lane. Replicate begins with Section 5-2 at milepost 348.37 and ends with Section 11-2 at milepost 348.67.

Table A-4. Layout of test sections at the Tremonton, Utah test site.

Replicate No.	Test Section No. (SHRP ID)	Sealant Material	Joint Configuration
1[a]	1 (49C440)	Koch 9012 hot-applied PVC-coal tar	C
	2 (49C441)	Koch 9005 hot-applied rubberized asphalt	C
	3 (49C410)	Dow 888-SL self-leveling silicone	C
	4 (49C430)	Unsealed	A
	5 (49C443)	Mobay Baysilone 960 non-sag silicone	C
	6 (49C444)	Esco PV 687 compression seal	C
	7 (49C445)	Kold Seal Neo Loop compression seal	B
	8 (49C446)	Dow 890-SL self-leveling silicone	A
	9 (49C447)	Mobay Baysilone 960 non-sag silicone	C
	10 (49C456)	Dow 890-SL self-leveling silicone	E
	11 (49C457)	Sealant supplied by Mike Roshek	C
	12 (49C458)	Unsealed	E
2[b]	13 (49C448)	Koch 9005 hot-applied rubberized asphalt	C
	14 (49C449)	Esco PV 687 compression seal	C
	15 (49C450)	Kold Seal Neo Loop compression seal	B
	16 (49C451)	Mobay Baysilone 960 non-sag silicone	C
	17 (49C452)	Koch 9012 hot-applied PVC-coal tar	C
	18 (49C431)	Unsealed	A
	19 (49C453)	Mobay Baysilone 960 non-sag silicone	C
	20 (49C454)	Dow 890-SL self-leveling silicone	A
	21 (49C455)	Dow 888-SL self-leveling silicone	C

[a] Replicate located in northbound and southbound driving lanes. Replicate begins in northbound lane with Section 1 at milepost 392.95 and extends through Section 9 at milepost 394.15. Replicate continues in southbound lane with Section 10 at milepost 395.09 and ends with Section 12 at milepost 394.82.

[b] Replicate located in southbound lane. Replicate begins with Section 13 at milepost 394.15 and ends with Section 21 at milepost 392.95.

Table A-5. Layout of test sections at the Salt Lake City, Utah test site.

Replicate No.	Test Section No. (SHRP ID)	Sealant Material	Joint Configuration
1[a]	1 (49D430)	Unsealed	A
	2 (49D410)	Dow 888-SL self-leveling silicone	C
	3 (49D443)	Dow 888 non-sag silicone	C
	4 (49D444)	D.S. Brown V-687 compression seal	C
	5 (49D441)	Crafco RS 221 hot-applied rubberized asphalt	C
	6 (49D446)	Dow 890-SL self-leveling silicone	A
	7 (49D440)	Koch 9012 hot-applied PVC-coal tar	C
	8 (49D445)	D.S. Brown E-437H compression seal	B
	9 (49D461)	Koch 9050-SL self-leveling polysulfide	C
	10 (49D456)	Dow 890-SL self-leveling silicone	E
	11 (49D458)	Unsealed	E
2[b]	22 (49D460)	Unsealed	E
	21 (49D459)	Dow 890-SL self-leveling silicone	E
	20 (49D462)	Koch 9050-SL self-leveling polysulfide	C
	19 (49D450)	D.S. Brown E-437H compression seal	B
	18 (49D452)	Koch 9012 hot-applied PVC-coal tar	C
	17 (49D454)	Dow 890-SL self-leveling silicone	A
	16 (49D448)	Crafco RS 221 hot-applied rubberized asphalt	C
	15 (49D449)	D.S. Brown V-687 compression seal	C
	14 (49D451)	Dow 888 non-sag silicone	C
	13 (49D455)	Dow 888-SL self-leveling silicone	C
	12 (49D431)	Unsealed	A

[a] Replicate located in southbound lanes. Replicate begins with Section 1 at station 121+00 and ends with Section 11 at station 168+00.

[b] Replicate located in northbound lanes. Replicate begins with Section 22 at station 168+00 and ends with Section 12 at station 121+00.

Table A-6. Layout of test sections at the Heber City, Utah test site.

Replicate No.	Test Section No. (SHRP ID)	Sealant Material	Joint Configuration
1[a]	1 (49E460)	Unsealed	E
	2 (49E459)	Dow 890-SL self-leveling silicone	E
	3 (49E462)	Koch 9050-SL self-leveling polysulfide	C
	4 (49E449)	D.S. Brown V-687 compression seal	C
	5 (49E448)	Koch 9005 hot-applied rubberized asphalt	C
	6 (49E450)	D.S. Brown E-437 H compression seal	B
	7 (49E454)	Dow 890-SL self-leveling silicone	A
	8 (49E452)	Koch 9012 hot-applied PVC-coal tar	C
	9 (49E451)	Dow 888 non-sag silicone	C
	10 (49E455)	Dow 888-SL self-leveling silicone	C
	11 (49E431)	Unsealed	A
2[b]	12 (49E430)	Unsealed	A
	13 (49E410)	Dow 888-SL self-leveling silicone	C
	14 (49E443)	Dow 888 non-sag silicone	C
	15 (49E441)	Koch 9005 hot-applied rubberized asphalt	C
	16 (49E444)	D.S. Brown V-687 compression seal	C
	17 (49E446)	Dow 890-SL self-leveling silicone	A
	18 (49E440)	Koch 9012 hot-applied PVC-coal tar	C
	19 (49E445)	D.S. Brown E-437 H compression seal	B
	20 (49E461)	Koch 9050-SL self-leveling polysulfide	C
	21 (49E456)	Dow 890-SL self-leveling silicone	E
	22 (49E458)	Unsealed	E

[a] Replicate located in westbound lanes. Replicate begins with Section 1 at station 500+00 and ends with Section 11 at station 444+00.

[b] Replicate located in eastbound lanes. Replicate begins with Section 12 at station 444+00 and ends with Section 22 at station 500+00.

APPENDIX B. INSTALLATION DATA

During installation of the test sites, several items were documented. These items included sawing and joint dimensions, depth to the top of sealant, and depth to the top of backer rod. Statistical analyses were performed on these data, the complete results of which are presented in this appendix. Tables that are included for each site are as follows:

- Average sawing and joint dimensions.
- Comparison of sawcut widths to specified widths.
- Comparison of depths to top of sealant to specified range.
- Comparison of depths to backer rod to specified range.
- Summary of sealant shape factors.

Table B-1. Average sawing and installation dimensions at Mesa, Arizona (Meier, 1992).

Section No.	Joint Width, mm	Joint Depth, mm	Depth to Top of Backer Rod, mm	Depth to Top of Seal, mm
1	9.6	102.4	—	7.0
2	9.8	106.8	15.0	6.6
3	No data, unsealed section			
4	9.6	103.1	17.9	7.4
5	9.8	—	—	—
6	9.5	105.1	15.5	6.4
7	9.6	108.0	15.7	7.9
8	10.4	104.0	17.0	7.3
9	5.2	106.0	16.1	5.7
10	10.2	107.1	16.8	7.6
11	9.6	105.1	15.1	4.2
12	11.1	105.7	18.7	8.0
13	4.8	108.2	15.4	4.4
14	9.8	113.9	—	9.3
15	9.8	113.6	16.9	8.0
16	9.5	113.5	15.4	6.1
17	4.2	—	—	—
18	10.4	102.4	16.5	7.1
19	10.1	107.1	17.3	6.0
20	10.7	105.5	15.8	5.8
21	10.3	111.3	16.0	4.7
22	9.9	95.9	—	—
23	9.9	110.4	17.8	4.6
24	7.1	107.6	14.4	4.8

Table B-2. Comparison of sawcut width to specified widths at Mesa, Arizona (Meier, 1992).

Section No.	Sawcut Width (mm)		Standard Deviations for:		Percentage Beyond Specified Limits		
	Mean	Std. Dev.	UL	LL	LL	UL	Total
1	9.6	0.40	4.26	3.76	0	0	0
2	9.8	0.62	3.00	2.08	0.001	0.019	0.020
3	No data, unsealed section						
4	9.6	0.41	4.14	3.62	0	0	0
5	9.8	0.64	2.92	2.02	0.002	0.022	0.024
6	9.5	0.00	Infinity	Infinity	0	0	0
7	9.6	0.39	4.36	3.87	0	0	0
8	10.4	2.05	1.20	0.35	0.155	0.363	0.518
9	5.2	0.79	4.51	0.5	0	0.691	0.691
10	10.2	0.84	2.74	1.05	0.003	0.147	0.150
11	9.6	0.41	4.14	3.62	0	0	0
12	11.1	0.00	Infinity	Infinity	0	0	0
13	4.8	0.92	3.46	0	0	0.500	0.500
14	9.8	0.58	3.15	2.36	0.001	0.009	0.010
15	9.8	0.94	2.01	1.38	0.023	0.084	0.107
16	9.5	0.00	Infinity	Infinity	0	0	0
17	4.2	1.28	2.02	0.46	0.022	0.323	0.345
18	10.4	1.39	1.75	0.54	0.040	0.295	0.335
19	10.1	0.83	2.63	1.20	0.004	0.118	0.122
20	10.7	1.27	2.17	0.33	0.015	0.371	0.386
21	10.3	0.82	2.84	1.03	0.002	0.152	0.154
22	9.9	0.72	2.76	1.66	0.003	0.048	0.051
23	9.9	0.71	2.79	1.68	0.003	0.046	0.049
24	7.1	1.12	2.12	0.71	0.017	0.239	0.256

LL=Lower limit: 1.6 mm for sections 9, 13, and 17; 4.8 mm for section 24; 8.0 mm for all other sections.
UL=Upper limit: 4.8 mm for sections 9, 13, and 17; 8.0 mm for section 24; 11.1 mm for all other sections.

Table B-3. Comparison of depths to top of sealant to specified range at Mesa, Arizona (Meier, 1992).

Section No.	Depth to Top of Seal, mm		Standard Deviations for:		Percentage Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
1	7.0	1.02	0.62	2.50	0.268	0.006	0.274
2	6.6	1.24	0.16	2.39	0.436	0.008	0.444
3	No data, unsealed section						
4	7.4	2.03	0.52	1.04	0.302	0.149	0.451
5	No data, Watson Bowman compression seal						
6	6.4	1.57	0	2.02	0.500	0.022	0.522
7	7.9	1.02	1.55	1.58	0.061	0.057	0.118
8	7.3	2.24	0.43	0.99	0.334	0.161	0.495
9	5.7	1.73	-0.37	2.21	0.644	0.014	0.658
10	7.6	1.32	0.92	1.48	0.179	0.069	0.248
11	4.2	1.37	-1.57	3.89	0.942	0	0.942
12	8.0	1.42	1.16	1.07	0.123	0.142	0.265
13	4.4	2.59	-0.74	1.96	0.770	0.025	0.795
14	9.3	1.68	1.79	0.11	0.037	0.456	0.493
15	8.0	0.99	1.67	0.94	0.047	0.174	0.221
16	6.1	1.63	-0.16	2.11	0.564	0.017	0.581
17	No data, unsealed section						
18	7.1	1.70	0.55	1.45	0.291	0.074	0.365
19	6.0	1.30	-0.23	2.69	0.591	0.004	0.595
20	5.8	1.78	-0.31	2.10	0.622	0.018	0.640
21	4.7	1.24	-1.33	3.88	0.908	0	0.908
22	No data, Watson Bowman compression seal section						
23	4.6	1.65	-1.05	2.97	0.853	0.001	0.854
24	4.8	1.32	-2.54	4.94	0.994	0	0.994

LL=Lower limit of 6.4 mm.
UL=Upper limit of 9.5 mm.

Table B-4. Comparison of depths to backer rod to specified range at Mesa, Arizona (Meier, 1992).

Section No.	Depth to Top of Backer Rod, mm		Standard Deviations for:		Percentage Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
1	No data, compression seal section						
2	15.0	0.91	2.50	4.44	0.006	0	0.006
3	No data, unsealed section						
4	17.9	0.97	5.39	1.18	0	0.119	0.119
5	No data, compression seal section						
6	15.5	1.02	2.80	3.45	0.003	0	0.003
7	15.7	0.64	4.80	5.2	0	0	0
8	17.0	1.19	3.57	1.74	0	0.041	0.041
9	16.1	1.80	1.90	1.62	0.029	0.053	0.082
10	16.8	1.12	3.75	1.93	0	0.027	0.027
11	15.1	1.22	1.98	3.23	0.024	0.001	0.025
12	18.7	0.84	7.12	0.45	0	0.326	0.326
13	15.4	2.03	1.31	1.81	0.095	0.035	0.130
14	No data, compression seal section						
15	16.9	0.89	4.77	2.37	0	0.009	0.009
16	15.4	0.97	2.84	3.74	0.002	0	0.002
17	No data, unsealed section						
18	16.5	1.22	3.12	2.08	0.001	0.019	0.020
19	17.3	1.37	3.37	1.26	0	0.104	0.104
20	15.8	0.97	3.21	3.37	0.001	0	0.001
21	16.0	1.19	2.77	2.55	0.003	0.005	0.008
22	No data, compression seal section.						
23	17.8	1.57	3.23	0.81	0.001	0.209	0.210
24	14.4	1.12	1.55	4.14	0.061	0	0.061

LL=Lower limit of 12.7 mm.
UL=Upper limit of 19.1 mm.

Table B-5. Summary of sealant shape factors at Mesa, Arizona (Meier, 1992).

Section No.	Shape Factor		Remarks
	Mean	Standard Deviation	
1	—	—	Compression seal section
2	1.24	0.21	
3	—	—	Unsealed section
4	1.07	0.54	
5	—	—	Compression seal section
6	1.08	0.28	
7	1.25	0.26	
8	1.10	0.32	
9	0.58	0.16	
10	1.16	0.24	
11	0.93	0.16	
12	1.07	0.18	
13	0.62	0.32	
14	—	—	Compression seal section
15	1.17	0.23	
16	1.14	0.29	
17	—	—	Unsealed section
18	1.13	0.32	
19	0.95	0.19	
20	1.08	0.20	
21	0.91	0.12	
22	—	—	Compression seal section
23	0.78	0.13	
24	0.61	0.08	

Table B-6. Average sawing and installation dimensions at Campo, Colorado (Ambroz and Evans, 1996).

Section No.	Joint Width, mm	Joint Depth, mm	Depth to Top of Backer Rod, mm	Depth to Top of Seal, mm
1A (08A430)	4.8	—	—	—
2A (08A410)	6.4	—	10.9	5.3
3A (08A441)	4.8	—	10.1	1.5
4A (08A411)	10.4	37.8	13.7	4.6
5A (08A442)	9.7	36.3	10.4	2.3
6A (08A451)	9.7	37.6	—	6.1
7A (08A412)	0	34.5	15.2	7.6
8A (08A443)	9.7	34.3	13.2	1.0
9A (08A452)	9.7	37.1	—	4.1
10A (08A453)	0	33.8	13.5	7.6
1B (08A431)	4.8	—	—	—
2B (08A413)	5.8	—	7.4	3.6
3B (08A444)	6.4	—	12.5	2.3
4B (08A414)	9.7	29.0	10.7	4.3
5B (08A445)	6.4	38.9	9.9	5.1
6B (08A454)	Transition zone			
7B (08A415)	9.7	—	—	—
8B (08A446)	9.7	39.6	13.5	5.1
9B (08A455)	—	—	—	—
10B (08A416)	—	—	—	—

Table B-7. Comparison of sawcut widths to specified widths at Campo, Colorado (Ambroz and Evans, 1996).

Section No.	Sawcut Width, mm		Standard Deviations for:		Percentage Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
1A (08A430)	4.8	0.00	Infinity	Infinity	0.0	0.0	0.0
2A (08A410)	6.4	0.00	Infinity	Infinity	0.0	100.0	100.0
3A (08A441)	4.8	0.00	Infinity	Infinity	0.0	0.0	0.0
4A (08A411)	10.4	1.02	5.56	-2.44	0.0	99.3	99.3
5A (08A442)	9.7	0.00	Infinity	Infinity	0.0	100.0	100.0
6A (08A451)	9.7	0.00	Infinity	Infinity	0.0	100.0	100.0
7A (08A412)	12.7	0.00	Infinity	Infinity	0.0	100.0	100.0
8A (08A443)	9.7	0.00	Infinity	Infinity	0.0	0.0	0.0
9A (08A452)	9.7	0.00	Infinity	Infinity	0.0	0.0	0.0
10A (08A453)	12.7	0.00	Infinity	Infinity	0.0	0.0	0.0
1B (08A431)	4.8	0.00	Infinity	Infinity	0.0	0.0	0.0
2B (08A413)	5.8	0.76	5.58	-1.42	0.0	92.2	92.2
3B (08A444)	6.4	0.00	Infinity	Infinity	0.0	0.0	0.0
4B (08A414)	9.7	0.00	Infinity	Infinity	0.0	0.0	0.0
5B (08A445)	6.4	0.00	Infinity	Infinity	0.0	0.0	0.0
6B (08A454)	Transition section						
7B (08A415)	9.7	0.00	Infinity	Infinity	0.0	0.0	0.0
8B (08A446)	9.7	0.00	Infinity	Infinity	0.0	0.0	0.0
9B (08A455)	—	—	—	—	—	—	—
10B (08A416)	—	—	—	—	—	—	—

Note: LL and UL are lower limit and upper limit, which are 1.59 mm less than and greater than the specified width, respectively.

Table B-8. Comparison of depths to top of sealant to specified range at Campo, Colorado (Ambroz and Evans, 1996).

Section No.	Joint Seal Recess, mm		Standard Deviations for:		Percentage Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
1A (08A430)	No data, unsealed section						
2A (08A410)	5.3	0.76	-1.33	5.50	90.8	0.0	90.8
3A (08A441)	1.5	1.52	-3.17	5.25	100.0	0.0	100.0
4A (08A411)	4.6	1.02	-1.75	4.88	96.0	0.0	96.0
5A (08A442)	2.3	1.52	-2.67	4.75	99.6	0.0	99.6
6A (08A451)	6.1	3.30	-0.08	1.04	53.2	14.9	68.1
7A (08A412)	7.6	1.27	1.00	1.50	15.9	6.7	22.6
8A (08A443)	1.0	1.52	-3.50	5.58	100.0	0.0	100.0
9A (08A452)	4.1	4.32	-0.53	1.26	70.2	10.4	80.6
10A (08A453)	7.6	2.54	0.50	0.80	30.9	21.1	52.0
1B (08A431)	No data, unsealed section						
2B (08A413)	3.6	1.52	-1.83	3.92	96.6	0.0	96.6
3B (08A444)	2.3	1.52	-2.67	4.75	99.6	0.0	99.6
4B (08A414)	4.3	1.78	-1.14	2.93	87.3	0.2	87.5
5B (08A445)	5.1	1.27	-1.00	3.50	84.1	0.0	84.1
6B (08A454)	Transition section						
7B (08A415)	No data collected						
8B (08A446)	5.1	1.02	-1.25	4.38	89.4	0.0	89.4
9B (08A455)	No data collected						
10B (08A416)	No data collected						

Note: LL and UL are lower limit and upper limit, which are 6.4 mm and 9.5 mm, respectively.

Table B-9. Comparison of depths to backer rod to specified range at Campo, Colorado (Ambroz and Evans, 1996).

Section No.	Backer Rod Depth, mm		Standard Deviations for:		Percentage Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
1A (08A430)	No data, unsealed section						
2A (08A410)	10.9	1.27	-1.40	6.40	91.9	0.0	91.9
3A (08A441)	10.2	1.02	-2.50	8.75	99.4	0.0	99.4
4A (08A411)	13.7	1.27	0.80	4.20	21.2	0.0	21.2
5A (08A442)	10.4	1.27	-1.80	6.80	96.4	0.0	96.4
6A (08A451)	No data, compression seal						
7A (08A412)	15.2	1.52	1.67	2.50	4.8	0.6	5.4
8A (08A443)	13.2	1.02	0.50	5.75	30.9	0.0	30.9
9A (08A452)	No data, compression seal						
10A (08A453)	13.5	0.76	1.0	7.33	15.9	0.0	15.9
1B (08A431)	No data, unsealed section						
2B (08A413)	7.4	3.30	-1.62	3.54	94.7	0.0	94.7
3B (08A444)	12.4	2.29	-0.11	2.89	54.4	0.2	54.6
4B (08A414)	10.7	3.30	-0.62	2.54	73.2	0.6	73.8
5B (08A445)	9.9	1.78	-1.57	5.14	94.2	0.0	94.2
6B (08A454)	Transition section						
7B (08A415)	No data collected						
8B (08A446)	13.5	1.78	0.43	3.14	33.4	0.0	33.4
9B (08A455)	No data collected						
10B (08A416)	No data collected						

Note: LL and UL are lower limit and upper limit, which are 12.7 mm and 19.1 mm, respectively.

Table B-10. Summary of sealant shape factors at Campo, Colorado (Ambroz and Evans, 1996).

Section No.	Shape Factor (depth/width)		Remarks
	Required	Mean	
1A (08A430)	—	—	Unsealed
2A (08A410)	2.0	0.81	Wide joints
3A (08A441)	2.0	1.67	
4A (08A411)	1.0	0.83	
5A (08A442)	1.0	0.77	
6A (08A451)	—	—	Compression seal
7A (08A412)	0.67	0.56	
8A (08A443)	0.67	1.25	Thick sealant
9A (08A452)	—	—	Compression seal
10A (08A453)	0.67	0.32	Wide joint, thin sealant
1B (08A431)	—	—	Unsealed
2B (08A413)	2.0	0.5	Wide joint, thin sealant
3B (08A444)	2.0	1.43	
4B (08A414)	1.0	0.77	
5B (08A445)	1.0	0.71	
6B (08A454)	—	—	Transition section
7B (08A415)	0.67	—	Data not collected
8B (08A446)	0.67	0.83	
9B (08A455)	—	—	Designed for compression seal
10B (08A416)	—	—	Designed for compression seal

Table B-11. Average sawing and installation dimensions at Wells, Nevada (Wienrank and Evans, 1995a).

Section No.	Joint Width, mm	Joint Depth, mm	Depth to Top of Backer Rod, mm	Depth to Top of Seal, mm
1 (323010)	—	—	—	—
2 (32A420)	10.0	37.2	17.5	11.1
3 (32A410)	13.0	37.2	17.5	10.3
4 (32A430)	—	—	—	—
5-1 (32A451)	10.5	40.0	17.1	7.1
6-1 (32A452)	9.7	40.5	18.3	8.5
7-1 (32A453)	10.5	40.5	16.8	7.8
8-1 (32A454)	14.0	46.7	—	10.8
9-1 (32A455)	12.7	38.7	19.5	9.3
10-1 (32A456)	13.5	42.2	20.2	8.2
11-1 (32A457)	10.5	39.7	20.3	12.2
5-2 (32A458)	10.2	39.5	19.7	8.6
6-2 (32A459)	14.0	44.9	18.1	10.5
7-2 (32A460)	9.9	40.0	16.4	9.5
8-2 (32A461)	13.3	45.4	—	11.9
9-2 (32A462)	12.4	40.6	16.4	8.7
10-2 (32A463)	13.7	42.5	17.9	8.0
11-2 (32A464)	9.7	38.4	19.1	8.4

Table B-12. Comparison of sawcut widths to specified widths at Wells, Nevada (Wienrank and Evans, 1995a).

Section No.	Sawcut Width, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
323010	No data, existing GPS left undisturbed						
32A410	13.0	4.60	1.10	-0.41	0.136	0.659	0.795
32A420	10.0	1.07	1.93	1.04	0.027	0.149	0.176
32A430	No data						
32A451	10.5	1.52	1.66	0.41	0.049	0.341	0.390
32A452	9.7	0.51	3.48	2.85	0.000	0.002	0.002
32A453	10.5	1.52	1.66	0.41	0.049	0.341	0.390
32A454	14.0	1.24	2.28	0.25	0.011	0.401	0.412
32A455	12.7	0.00	Infinity	Infinity	0.000	1.000	1.000
32A456	13.5	1.73	3.24	-1.39	0.001	0.918	0.919
32A457	10.5	1.52	1.66	0.41	0.049	0.341	0.390
32A458	10.2	1.35	1.66	0.71	0.049	0.239	0.288
32A459	10.2	1.40	1.64	0.63	0.051	0.264	0.315
32A460	9.9	1.02	1.90	1.26	0.029	0.104	0.133
32A461	13.3	0.81	2.71	1.16	0.003	0.123	0.126
32A462	12.4	1.02	4.43	-1.26	0.000	0.896	0.896
32A463	13.7	1.70	3.35	-1.49	0.001	0.932	0.933
32A464	9.7	0.51	3.48	2.85	0.000	0.002	0.002

Note: LL and UL are lower limit and upper limit, which are 1.59 mm less than and greater than the specified width, respectively.

Table B-13. Comparison of depths to top of sealant to specified range at Wells, Nevada (Wienrank and Evans, 1995a).

Section No.	Depth to Top of Joint Sealant, mm		Standard Deviations		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
323010	No data, existing GPS left undisturbed						
32A410	10.3	1.91	2.09	-0.42	0.018	0.663	0.681
32A420	11.1	3.18	1.50	-0.50	0.067	0.692	0.759
32A430	No data, unsealed section						
32A451	7.1	2.97	0.24	0.83	0.405	0.203	0.608
32A452	8.5	4.34	0.49	0.24	0.312	0.405	0.717
32A453	7.8	3.51	0.40	0.50	0.345	0.309	0.654
32A454	10.8	2.08	2.13	-0.61	0.017	0.729	0.746
32A455	9.3	1.57	1.89	0.13	0.029	0.448	0.477
32A456	8.2	2.11	0.88	0.63	0.189	0.264	0.453
32A457	12.2	3.66	1.60	-0.74	0.055	0.770	0.825
32A458	8.6	2.64	0.87	0.33	0.192	0.371	0.563
32A459	10.5	2.24	1.86	-0.44	0.031	0.670	0.701
32A460	9.5	2.79	1.13	0.00	0.129	0.500	0.629
32A461	11.9	1.88	2.97	-1.27	0.002	0.898	0.900
32A462	8.7	1.55	1.54	0.51	0.062	0.305	0.367
32A463	8.0	2.36	0.67	0.67	0.251	0.251	0.502
32A464	8.4	2.79	0.74	0.40	0.230	0.345	0.575

Note: LL and UL are lower limit and upper limit, which are 6.4 mm and 9.5 mm, respectively.

Table B-14. Comparison of depths to backer rod to specified range at Wells, Nevada (Wienrank and Evans, 1995a).

Section No.	Depth to Top of Backer Rod, mm		Standard Deviations		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
323010	No data, existing GPS left undisturbed						
32A410	17.5	4.04	1.18	0.39	0.119	0.348	0.467
32A420	17.5	1.30	3.67	1.22	0.000	0.111	0.111
32A430	No data, unsealed section						
32A451	17.1	3.33	1.33	0.57	0.092	0.284	0.376
32A452	18.3	2.16	2.58	0.37	0.005	0.356	0.361
32A453	16.8	3.76	1.10	0.59	0.136	0.278	0.414
32A454	No data, compression seal						
32A455	19.5	2.79	2.43	-0.17	0.008	0.568	0.576
32A456	20.2	3.81	1.95	-0.29	0.026	0.614	0.640
32A457	20.3	2.57	2.96	-0.49	0.002	0.688	0.690
32A458	19.7	3.02	2.32	-0.21	0.010	0.583	0.593
32A459	18.1	3.68	1.47	0.26	0.071	0.397	0.468
32A460	16.4	4.37	0.84	0.62	0.201	0.268	0.469
32A461	No data, compression seal						
32A462	16.4	1.83	1.98	1.47	0.024	0.071	0.095
32A463	17.9	2.79	1.87	0.40	0.031	0.345	0.376
32A464	19.1	1.50	4.24	0.00	0.000	0.500	0.500

Note: LL and UL are lower limit and upper limit, which are 12.7 mm and 19.1 mm, respectively.

Table B-15. Summary of sealant shape factors at Wells, Nevada (Wienrank and Evans, 1995a).

Section No.	Shape Factor (depth/width)		Remarks
	Mean	Std. Dev.	
323010	—	—	Undisturbed section
32A410	0.571	0.461	
32A420	0.440	0.441	
32A430	—	—	Unsealed section
32A451	0.938	0.658	
32A452	0.919	0.584	
32A453	0.792	0.381	
32A454	—	—	Compression seal
32A455	0.625	0.363	
32A456	0.558	0.507	
32A457	0.792	0.464	
32A458	1.017	0.551	
32A459	0.445	0.368	
32A460	0.688	0.414	
32A461	—	—	Compression seal
32A462	0.625	0.212	
32A463	0.735	0.341	
32A464	1.107	0.302	

Table B-16. Average sawing and installation dimensions at Tremonton, Utah (Wienrank and Evans, 1995b).

Section No.	Joint Width, mm	Joint Depth, mm	Depth to Top of Backer Rod, mm	Depth to Top of Seal, mm
1 (49C440)	10.2	30.8	15.9	—
2 (49C441)	10.3	33.2	16.7	5.7
3 (49C410)	10.3	36.3	15.6	7.3
4 (49C430)	4.8	84.0	—	—
5 (49C443)	—	—	—	—
6 (49C444)	10.3	34.1	—	—
7 (49C445)	8.6	46.8	—	—
8 (49C446)	4.8	81.3	17.9	—
9 (49C447)	9.7	34.1	17.3	7.5
10 (49C456)	4.8	33.5	16.4	—
11 (49C457)	—	—	—	—
12 (49C458)	—	—	—	—
13 (49C448)	10.0	35.3	15.9	6.2
14 (49C449)	9.0	34.3	—	—
15 (49C450)	8.4	49.4	—	—
16 (49C451)	10.2	32.5	17.3	7.5
17 (49C452)	10.2	34.1	17.0	5.7
18 (49C431)	4.9	84.8	—	—
19 (49C453)	—	—	—	—
20 (49C454)	4.8	78.1	15.7	—
21 (49C455)	11.3	31.4	17.6	6.4

Table B-17. Comparison of sawcut widths to specified widths at Tremonton, Utah (Wienrank and Evans, 1995b).

Section No.	Sawcut Width, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49C410	10.3	0.84	2.85	0.95	0.002	0.171	0.173
49C430	4.8	0.00	Infinity	Infinity	0.000	0.000	0.000
49C431	4.9	0.51	6.64	-0.32	0.000	0.626	0.626
49C440	10.2	0.81	2.71	1.16	0.003	0.123	0.126
49C441	10.3	0.84	2.85	0.95	0.002	0.171	0.173
49C443	No data						
49C444	10.3	0.84	2.85	0.95	0.002	0.171	0.173
49C445	8.6	0.81	4.65	-0.77	0.000	0.779	0.779
49C446	4.8	0.00	Infinity	Infinity	0.000	0.000	0.000
49C447	9.7	0.51	3.48	2.85	0.000	0.002	0.002
49C448	10.0	0.76	2.69	1.45	0.004	0.074	0.078
49C449	9.0	1.07	1.04	1.93	0.149	0.027	0.176
49C450	8.4	0.76	4.76	-0.62	0.000	0.732	0.732
49C451	10.2	0.81	2.71	1.16	0.003	0.123	0.126
49C452	10.2	0.81	2.71	1.16	0.003	0.123	0.126
49C453	No data						
49C454	4.8	0.00	Infinity	Infinity	0.000	0.000	0.000
49C455	11.3	0.89	3.70	-0.18	0.000	0.571	0.571
49C456	4.8	0.00	Infinity	Infinity	0.000	0.000	0.000
49C457	No data						
49C458	No data						

Note: LL and UL are lower limit and upper limit, which are 1.6 mm less than and greater than the specified width, respectively.

Table B-18. Comparison of depths to top of sealant to specified range at Tremonton, Utah (Wienrank and Evans, 1995b).

Section No.	Depth to Top of Seal, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49C410	7.3	1.12	0.86	2.00	0.195	0.023	0.218
49C430	No data, unsealed section						
49C431	No data, unsealed section						
49C440	No data						
49C441	5.7	0.81	-0.77	4.65	0.779	0.000	0.779
49C443	No data						
49C444	No data						
49C445	No data						
49C446	No data						
49C447	7.5	1.07	1.04	1.93	0.149	0.027	0.176
49C448	6.2	0.89	-0.18	3.70	0.571	0.000	0.571
49C449	No data						
49C450	No data						
49C451	7.5	1.07	1.04	1.93	0.149	0.027	0.176
49C452	5.7	0.81	-0.77	4.65	0.779	0.000	0.779
49C453	No data						
49C454	No data						
49C455	6.4	1.30	0.00	2.45	0.500	0.007	0.507
49C456	No data						
49C457	No data						
49C458	No data, unsealed section						

Note: LL and UL are lower limit and upper limit, which are 6.4 mm and 9.5 mm, respectively.

Table B-19. Comparison of depths to backer rod to specified range at Tremonton, Utah (Wienrank and Evans, 1995b).

Section No.	Depth to Top of Backer Rod, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49C410	15.6	1.24	2.28	2.79	0.011	0.003	0.014
49C430	No data, unsealed section						
49C431	No data, unsealed section						
49C440	15.9	1.30	2.45	2.45	0.007	0.007	0.014
49C441	16.7	1.35	2.94	1.77	0.002	0.038	0.040
49C443	No data						
49C444	No data, compression seal						
49C445	No data, compression seal						
49C446	17.9	1.07	4.89	1.04	0.000	0.149	0.149
49C447	17.3	0.89	5.11	1.94	0.000	0.026	0.026
49C448	15.9	1.30	2.45	2.45	0.007	0.007	0.014
49C449	No data, compression seal						
49C450	No data, compression seal						
49C451	17.3	1.17	3.93	1.49	0.000	0.068	0.068
49C452	17.0	1.07	4.00	1.93	0.000	0.027	0.027
49C453	No data						
49C454	15.7	1.17	2.57	2.85	0.005	0.000	0.005
49C455	17.6	1.17	4.20	1.22	0.000	0.111	0.111
49C456	16.4	1.30	2.79	2.06	0.003	0.020	0.023
49C457	No data						
49C458	No data, unsealed section						

Note: LL and UL are lower limit and upper limit, which are 12.7 mm and 19.1 mm, respectively.

Table B-20. Summary of sealant shape factors at Tremonton, Utah (Wienrank and Evans, 1995b).

Section No.	Shape Factor (depth/width)		Remarks
	Mean	Std. Dev.	
49C410	0.798	0.177	
49C430	—	—	Unsealed section
49C431	—	—	Unsealed section
49C440	—	—	
49C441	1.062	0.080	
49C443	—	—	
49C444	—	—	Compression seal
49C445	—	—	Compression seal
49C446	—	—	
49C447	1.019	0.119	
49C448	0.969	0.122	
49C449	—	—	Compression seal
49C450	—	—	Compression seal
49C451	0.976	0.205	
49C452	1.112	0.111	
49C453	—	—	
49C454	—	—	
49C455	1.000	0.089	
49C456	—	—	
49C457	—	—	
49C458	—	—	Unsealed section

Table B-21. Average sawing and installation dimensions at Salt Lake City, Utah (Wienrank and Evans, 1995c).

Section No.	Joint Width, mm	Joint Depth, mm	Depth to Top of Backer Rod, mm	Depth to Top of Seal, mm
1 (49D430)	—	—	—	—
2 (49D410)	9.4	43.7	14.0	3.5
3 (49D443)	9.2	40.0	13.7	5.9
4 (49D444)	7.0	52.1	—	4.8
5 (49D441)	9.9	34.0	15.4	1.2
6 (49D446)	4.9	53.5	17.3	—
7 (49D440)	10.6	37.6	17.0	3.0
8 (49D445)	5.1	57.9	—	4.6
9 (49D461)	9.5	35.9	13.5	—
10 (49D456)	—	—	—	—
11 (49D458)	—	—	—	—
12 (49D431)	—	—	—	—
13 (49D455)	10.2	32.7	18.4	5.1
14 (49D451)	10.6	31.9	14.6	6.2
15 (49D449)	8.0	25.6	—	—
16 (49D448)	10.8	34.6	19.8	—
17 (49D454)	5.9	43.8	19.7	3.8
18 (49D452)	12.1	46.4	12.7	2.9
19 (49D450)	6.2	68.1	—	—
20 (49D462)	9.9	34.8	13.3	—
21 (49D459)	—	—	—	—
22 (49D460)	3.8	19.1	—	—

Table B-22. Comparison of sawcut widths to specified widths at Salt Lake City, Utah (Wienrank and Evans, 1995c).

Section No.	Sawcut Width, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49D410	9.4	0.51	2.85	3.48	0.0022	0.0002	0.002
49D430	No data, unsealed section						
49D431	No data, unsealed section						
49D440	10.6	0.76	3.52	0.62	0.000	0.268	0.268
49D441	9.9	1.02	1.90	1.26	0.029	0.104	0.133
49D443	9.2	0.66	1.90	2.85	0.029	0.002	0.031
49D444	7.0	0.81	-1.16	5.03	0.877	0.000	0.877
49D445	5.1	0.66	0.47	4.27	0.319	0.000	0.319
49D446	4.9	0.51	6.64	-0.32	0.000	0.626	0.626
49D448	10.8	0.66	4.27	0.47	0.000	0.319	0.319
49D449	8.0	0.74	0.00	4.24	0.500	0.000	0.500
49D450	6.2	0.51	2.85	3.48	0.002	0.000	0.002
49D451	10.6	0.76	3.52	0.62	0.000	0.268	0.268
49D452[a]	12.1	0.81	5.03	-1.16	0.000	0.877	0.877
49D452	10.3	0.84	2.85	0.95	0.002	0.171	0.173
49D454	5.9	0.76	5.59	-1.45	0.000	0.927	0.927
49D455	10.2	0.81	2.71	1.16	0.003	0.123	0.126
49D456	No data						
49D458	No data, unsealed section						
49D459	No data						
49D460	3.8	0.81	2.71	1.16	0.003	0.123	0.126
49D461	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49D462	9.9	0.66	2.85	1.90	0.002	0.029	0.031

[a] Section 49D452 was removed and reinstalled.

Note: LL and UL are lower limit and upper limit, which are 1.6 mm less than and greater than the specified width, respectively.

Table B-23. Comparison of depths to top of sealant to specified range at Salt Lake City, Utah (Wienrank and Evans, 1995c).

Section No.	Depth to Top of Seal, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49D410	3.5	1.91	-1.48	3.14	0.9306	0.001	0.932
49D430	No data, unsealed section						
49D431	No data, unsealed section						
49D440	3.0	2.18	-1.53	2.99	0.937	0.001	0.938
49D441	1.2	2.36	-2.18	3.53	0.985	0.000	0.985
49D443	5.9	1.30	-0.36	2.79	0.641	0.003	0.644
49D444	4.8	1.68	-0.95	2.85	0.829	0.002	0.831
49D445	4.6	1.17	-1.49	4.20	0.932	0.000	0.932
49D446	0.0	2.59	-2.45	3.67	0.993	0.000	0.993
49D448	No data						
49D449	No data						
49D450	No data						
49D451	6.2	0.89	-0.18	3.70	0.571	0.000	0.571
49D452[a]	2.9	1.02	-3.48	6.64	1.000	0.000	1.000
49D452	No data, removed and resealed						
49D454	3.8	2.92	-0.88	1.96	0.811	0.025	0.836
49D455	5.1	1.24	-1.01	3.55	0.844	0.000	0.844
49D456	No data						
49D458	No data, unsealed section						
49D459	No data						
49D460	No data, unsealed section						
49D461	No data						
49D462	No data						

[a] Section 49D452 was removed and reinstalled.

Note: LL and UL are lower limit and upper limit, which are 6.4 mm and 9.5 mm, respectively.

Table B-24. Comparison of depths to backer rod to specified range at Salt Lake City, Utah (Wienrank and Evans, 1995c).

Section No.	Depth to Top of Backer Rod, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49D410	14.0	1.24	1.01	4.06	0.156	0.000	0.156
49D430	No data, unsealed section						
49D431	No data, unsealed section						
49D440	17.0	1.30	3.28	1.58	0.001	0.057	0.058
49D441	15.4	2.36	1.14	1.54	0.127	0.062	0.189
49D443	13.7	1.85	0.51	2.90	0.305	0.002	0.307
49D444	No data, compression seal						
49D445	No data, compression seal						
49D446	17.3	1.91	2.42	0.92	0.008	0.179	0.187
49D448	19.8	1.12	6.36	-0.71	0.000	0.761	0.761
49D449	No data, compression seal						
49D450	No data, compression seal						
49D451	14.6	1.65	1.16	2.71	0.123	0.003	0.126
49D452[a]	12.7	1.07	0.00	6.00	0.500	0.000	0.500
49D452	19.7	1.70	4.09	-0.37	0.000	0.644	0.644
49D454	19.7	0.81	8.52	-0.77	0.000	0.779	0.779
49D455	18.4	1.12	5.15	0.57	0.000	0.284	0.284
49D456	No data, no backer rod used with Soff-Cut						
49D458	No data, unsealed section						
49D459	No data, no backer rod used with Soff-Cut						
49D460	No data, unsealed section						
49D461	13.5	1.73	0.46	3.24	0.323	0.001	0.324
49D462	13.3	0.81	0.77	6.97	0.221	0.000	0.221

[a] Section 49D452 was removed and reinstalled.

Note: LL and UL are lower limit and upper limit, which are 6.4 mm and 9.5 mm, respectively.

Table B-25. Summary of sealant shape factors at Salt Lake City, Utah (Wienrank and Evans, 1995c).

Section No.	Shape Factor (depth/width)		Remarks
	Mean	Std. Dev.	
49D410	1.013	0.421	
49D430	—	—	Unsealed section
49D431	—	—	Unsealed section
49D440	1.329	0.300	
49D441	1.462	0.374	
49D443	0.853	0.270	
49D444	—	—	Compression seal
49D445	—	—	Compression seal
49D446	2.475	1.752	
49D448	1.848	0.197	
49D449	—	—	Compression seal
49D450	—	—	Compression seal
49D451	0.793	0.207	
49D452[a]	0.821	0.133	[a] Second installation
49D452	—	—	
49D454	2.292	1.371	
49D455	1.324	0.202	
49D456	—	—	
49D458	—	—	Unsealed section
49D459	—	—	
49D460	—	—	Unsealed section
49D461	—	—	
49D462	—	—	

[a] Section 49D452 was removed and reinstalled.

Table B-26. Average sawing and installation dimensions at Heber City, Utah (Wienrank and Evans, 1995d).

Section No.	Joint Width, mm	Joint Depth, mm	Depth to Top of Backer Rod, mm	Depth to Top of Seal, mm
1 (49E460)	—	—	—	—
2 (49E459)	6.4	13.8	—	8.7
3 (49E462)	9.5	33.8	17.5	10.8
4 (49E449)	9.5	34.1	—	8.4
5 (49E448)	9.5	35.9	18.4	6.2
6 (49E450)	8.0	40.8	—	11.4
7 (49E454)	4.9	78.1	19.5	9.2
8 (49E452)	9.5	36.0	14.3	5.6
9 (49E451)	11.3	34.3	17.5	11.1
10 (49E455)	9.7	33.7	17.8	8.3
11 (49E431)	—	—	—	—
12 (49E430)	—	—	—	—
13 (49E410)	9.5	35.3	18.9	10.6
14 (49E443)	9.5	34.6	18.9	9.2
15 (49E441)	9.5	34.9	19.1	7.0
16 (49E444)	9.5	34.6	—	6.0
17 (49E446)	4.8	73.0	14.1	6.2
18 (49E440)	9.5	34.6	19.5	6.5
19 (49E445)	6.4	36.5	—	8.0
20 (49E461)	9.5	34.6	18.1	8.8
21 (49E456)	3.2	25.7	—	8.3
22 (49E458)	—	—	—	—

Table B-27. Comparison of sawcut widths to specified widths at Heber City, Utah (Wienrank and Evans, 1995d).

Section No.	Sawcut Width, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49E410	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E430	No data, unsealed section						
49E431	No data, unsealed section						
49E440	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E441	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E443	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E444	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E445	6.4	0.00	Infinity	Infinity	0.000	0.000	0.000
49E446	4.8	0.00	Infinity	Infinity	0.000	0.000	0.000
49E448	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E449	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E450	8.0	0.00	Infinity	Infinity	0.000	0.000	0.000
49E451	11.3	0.51	6.64	-0.32	0.000	0.623	0.623
49E452	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E454	4.9	0.51	6.64	-0.32	0.000	0.623	0.623
49E455	9.7	0.51	3.48	2.85	0.000	0.002	0.002
49E456	3.2	0.00	Infinity	Infinity	0.000	0.000	0.000
49E458	No data, unsealed section						
49E459	6.4	0.00	Infinity	Infinity	0.000	1.000	1.000
49E460	No data, unsealed section						
49E461	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000
49E462	9.5	0.00	Infinity	Infinity	0.000	0.000	0.000

Note: LL and UL are lower limit and upper limit, which are 1.6 mm less than and greater than the specified width, respectively.

Table B-28. Comparison of depths to top of sealant to specified range at Heber City, Utah (Wienrank and Evans, 1995d).

Section No.	Depth to Top of Seal, mm		Standard Deviations for:		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49E410	10.6	2.69	1.59	-0.41	0.056	0.659	0.715
49E430	No data, unsealed section						
49E431	No data, unsealed section						
49E440	6.5	2.03	0.08	1.48	0.468	0.069	0.537
49E441	7.0	1.52	0.41	1.66	0.341	0.049	0.390
49E443	9.2	1.45	1.96	0.22	0.025	0.413	0.438
49E444	6.0	0.66	-0.47	5.22	0.681	0.000	0.681
49E445	8.0	1.07	1.50	1.50	0.067	0.067	0.134
49E446	6.2	1.17	-0.14	2.85	0.556	0.002	0.558
49E448	6.2	2.03	-0.08	1.63	0.532	0.052	0.584
49E449	8.4	1.50	1.37	0.74	0.085	0.230	0.315
49E450	11.4	1.45	3.48	-1.31	0.000	0.905	0.905
49E451	11.1	1.30	3.67	-1.22	0.000	0.889	0.889
49E452	5.6	2.51	-0.32	1.58	0.626	0.057	0.683
49E454	9.2	1.80	1.59	0.18	0.056	0.429	0.485
49E455	8.3	2.34	0.81	0.54	0.209	0.295	0.504
49E456	8.3	3.71	0.52	0.33	0.302	0.371	0.673
49E458	No data, unsealed section						
49E459	8.7	2.39	0.99	0.33	0.161	0.371	0.532
49E460	No data, unsealed section						
49E461	8.8	2.11	1.17	0.33	0.121	0.371	0.492
49E462	10.8	3.66	1.22	-0.35	0.111	0.637	0.748

Note: LL and UL are lower limit and upper limit, which are 6.4 mm and 9.5 mm, respectively.

Table B-29. Comparison of depths to backer rod to specified range at Heber City, Utah (Wienrank and Evans, 1995d).

Section No.	Depth to Top of Backer Rod, mm		Standard Deviations		Portion Beyond Specified Limits		
	Mean	Std. Dev.	LL	UL	LL	UL	Total
49E410	18.9	0.89	6.87	0.18	0.000	0.429	0.429
49E430	No data, unsealed section						
49E431	No data, unsealed section						
49E440	19.5	1.07	6.37	-0.44	0.000	0.670	0.670
49E441	19.1	1.50	4.24	0.00	0.000	0.500	0.500
49E443	18.9	0.89	6.87	0.18	0.000	0.429	0.429
49E444	No data, compression seal						
49E445	No data, compression seal						
49E446	14.1	2.03	0.70	2.41	0.242	0.008	0.250
49E448	18.4	0.81	6.97	0.77	0.000	0.221	0.221
49E449	No data, compression seal						
49E450	No data, compression seal						
49E451	17.5	1.30	3.67	1.22	0.000	0.111	0.111
49E452	14.3	1.50	1.06	3.18	0.145	0.001	0.146
49E454	19.5	2.13	3.21	-0.22	0.001	0.587	0.588
49E455	17.8	1.32	3.82	0.96	0.000	0.169	0.169
49E456	No data, no backer rod used with Soff-Cut						
49E458	No data, unsealed section						
49E459	No data, no backer rod used with Soff-Cut						
49E460	No data, unsealed section						
49E461	18.1	1.35	4.03	0.71	0.000	0.239	0.239
49E462	17.5	1.83	2.60	0.87	0.005	0.192	0.197

Note: LL and UL are lower limit and upper limit, which are 12.7 mm and 19.1 mm, respectively.

Table B-30. Summary of sealant shape factors at Heber City, Utah (Wienrank and Evans, 1995d).

Section No.	Shape Factor (depth/width)		Remarks
	Mean	Std. Dev.	
49E410	0.867	0.292	
49E430	—	—	Unsealed section
49E431	—	—	Unsealed section
49E440	1.367	0.246	
49E441	1.267	0.196	
49E443	1.017	0.214	
49E444	—	—	Compression seal
49E445	—	—	Compression seal
49E446	1.667	0.609	
49E448	1.283	0.261	
49E449	—	—	Compression seal
49E450	—	—	Compression seal
49E451	0.563	0.172	
49E452	0.917	0.275	
49E454	2.125	0.625	
49E455	0.600	0.634	
49E456	—	—	
49E458	—	—	Unsealed section
49E459	—	—	
49E460	—	—	Unsealed section
49E461	1.067	0.417	
49E462	0.700	0.436	

APPENDIX C. FIELD PERFORMANCE DATA

A large amount of field performance data was collected during the 4 years of SPS-4 supplemental joint seal test site monitoring. The data were stored in spreadsheets and the FHWA LTM database, and summaries of the field performance are contained in the tables in this appendix.

Table C-1. Transverse joint seal performance summary at Mesa, Arizona test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Crafco RS 221	C	1	53.8	24.9	85.0	97.7	99.2	9.1
Crafco RS 221	C	2	51.7	16.0	96.5	98.2	99.7	12.2
		Avg.	52.7	20.5	90.7	98.0	99.5	10.7
Crafco SS 444	C	1	100.0	99.9	2.5	97.7	99.8	2.1
Crafco SS 444	C	2	99.7	99.7	62.3	96.9	99.2	61.3
		Avg.	99.8	99.8	32.4	97.3	99.5	31.7
Crafco 903-SL	C	1	99.3	99.9	99.9	91.8	98.4	98.3
Crafco 903-SL	C	2	97.0	99.9	99.9	90.4	97.9	97.7
		Avg.	98.1	99.9	99.9	91.1	98.1	98.0
Dow 888	C	1	99.9	99.9	100.0	95.3	99.0	99.0
Dow 888	C	2	100.0	100.0	100.0	92.8	98.9	98.9
		Avg.	99.9	100.0	100.0	94.0	99.0	98.9
Dow 888-SL	C	1	97.7	99.4	100.0	93.8	98.7	98.1
Dow 888-SL	C	2	99.4	99.7	100.0	91.4	97.7	97.3
		Avg.	98.6	99.5	100.0	92.6	98.2	97.7
Dow 890-SL	A	1	96.7	99.2	100.0	95.0	99.2	98.4
Dow 890-SL	A	2	94.4	97.5	100.0	92.8	97.4	94.8
		Avg.	95.5	98.3	100.0	93.9	98.3	96.6
Dow 890-SL	B	1	98.7	99.9	100.0	94.3	99.1	99.0
Dow 890-SL	B	2	98.5	99.5	99.9	95.3	98.4	97.9
		Avg.	98.6	99.7	100.0	94.8	98.7	98.4
Dow 890-SL	C	1	99.2	99.6	100.0	96.4	99.7	99.2
Dow 890-SL	C	2	99.3	99.7	100.0	96.5	98.6	98.3
		Avg.	99.2	99.7	100.0	96.4	99.1	98.8
Mobay 960-SL	C	1	99.7	99.4	99.2	92.8	96.2	94.8
Mobay 960-SL	C	2	99.9	99.9	99.9	95.9	98.0	97.9
		Avg.	99.8	99.7	99.6	94.4	97.1	96.4
No Seal	A	1	100.0	100.0	100.0	96.8	99.2	99.2
No Seal	A	2	100.0	100.0	100.0	91.3	99.0	99.0
		Avg.	100.0	100.0	100.0	94.0	99.1	99.1

Table C-2. Overall transverse joint seal effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	67.9	50.7	18.1	9.1
		2	100.0	28.1	22.1	18.1	12.2
		Avg.	100.0	48.0	36.4	18.1	10.7
Crafco SS 444	C	1	100.0	83.6	30.6	10.8	2.3
		2	100.0	99.6	94.7	81.3	61.3
		Avg.	100.0	91.6	62.7	46.0	31.8
Crafco 903-SL	C	1	100.0	99.4	98.8	98.4	98.3
		2	100.0	99.1	98.3	97.8	97.7
		Avg.	100.0	99.3	98.6	98.1	98.0
Dow 888	C	1	100.0	99.5	99.3	99.1	99.0
		2	100.0	99.5	99.1	99.0	98.9
		Avg.	100.0	99.5	99.2	99.1	98.9
Dow 888-SL	C	1	100.0	99.3	98.8	98.4	98.1
		2	100.0	98.9	97.8	97.6	97.3
		Avg.	100.0	99.1	98.3	98.0	97.7
Dow 890-SL	A	1	100.0	99.6	99.2	98.8	98.4
		2	100.0	97.6	95.9	95.2	94.8
		Avg.	100.0	98.6	97.5	97.0	96.6
Dow 890-SL	B	1	100.0	99.7	99.4	99.1	99.0
		2	100.0	99.5	98.3	98.0	97.9
		Avg.	100.0	99.6	98.8	98.6	98.4
Dow 890-SL	C	1	100.0	99.7	99.6	99.4	99.2
		2	100.0	99.5	98.6	98.4	98.3
		Avg.	100.0	99.6	99.1	98.9	98.8
D.S. Brown V-687	C	1	100.0	61.8	41.3	28.8	26.6
		2	100.0	64.0	41.1	35.9	32.8
		Avg.	100.0	62.9	41.2	32.3	29.7
Mobay 960-SL	C	1	100.0	97.6	96.8	95.8	94.8
		2	100.0	98.9	98.2	98.1	97.9
		Avg.	100.0	98.2	97.5	97.0	96.4
Watson Bowman 687	C	1	100.0	97.7	95.5	91.1	87.2
Watson Bowman 812	C	1	100.0	99.9	96.9	93.5	90.3
No Seal	A	1	100.0	99.8	99.5	99.4	99.2
		2	100.0	99.5	99.1	99.0	99.0
		Avg.	100.0	99.7	99.3	99.2	99.1

Table C-3. Adhesion effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	71.1	55.6	24.2	24.9
		2	100.0	29.6	24.0	21.5	16.0
		Avg.	100.0	50.3	39.8	22.9	20.5
Crafco SS 444	C	1	100.0	99.1	98.8	99.5	99.9
		2	100.0	100.0	99.9	100.0	99.7
		Avg.	100.0	99.5	99.4	99.7	99.8
Crafco 903-SL	C	1	100.0	99.9	99.9	99.9	99.9
		2	100.0	99.9	99.9	99.9	99.9
		Avg.	100.0	99.9	99.9	99.9	99.9
Dow 888	C	1	100.0	100.0	100.0	100.0	99.9
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 888-SL	C	1	100.0	99.8	99.8	99.5	99.4
		2	100.0	99.8	99.8	99.8	99.7
		Avg.	100.0	99.8	99.8	99.7	99.5
Dow 890-SL	A	1	100.0	99.9	99.8	99.5	99.2
		2	100.0	98.8	98.3	97.7	97.5
		Avg.	100.0	99.4	99.0	98.6	98.3
Dow 890-SL	B	1	100.0	99.9	99.9	99.9	99.9
		2	100.0	99.9	99.8	99.6	99.5
		Avg.	100.0	99.9	99.9	99.8	99.7
Dow 890-SL	C	1	100.0	99.9	99.8	99.7	99.6
		2	100.0	99.9	99.8	99.7	99.7
		Avg.	100.0	99.9	99.8	99.7	99.7
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960-SL	C	1	100.0	99.9	99.7	99.3	99.4
		2	100.0	100.0	100.0	100.0	99.9
		Avg.	100.0	99.9	99.9	99.7	99.7
Watson Bowman 687	C	1	100.0	100.0	100.0	100.0	100.0
Watson Bowman 812	C	1	100.0	100.0	100.0	100.0	100.0
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0

Table C-4. Cohesion effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	97.3	95.8	94.7	85.0
		2	100.0	98.7	98.4	96.8	96.5
		Avg.	100.0	98.0	97.1	95.7	90.7
Crafco SS 444	C	1	100.0	84.7	32.0	11.5	2.5
		2	100.0	99.9	95.4	81.9	62.3
		Avg.	100.0	92.3	63.7	46.7	32.4
Crafco 903-SL	C	1	100.0	100.0	100.0	100.0	99.9
		2	100.0	100.0	100.0	99.8	99.9
		Avg.	100.0	100.0	100.0	99.9	99.9
Dow 888	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 888-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	99.9	99.9
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960-SL	C	1	100.0	99.9	100.0	99.9	99.2
		2	100.0	99.9	99.9	99.9	99.9
		Avg.	100.0	99.9	100.0	99.9	99.6
Watson Bowman 687	C	1	100.0	100.0	100.0	100.0	100.0
Watson Bowman 812	C	2	100.0	100.0	100.0	100.0	100.0
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0

Table C-5. Spall effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	99.5	99.3	99.2	99.2
		2	100.0	99.8	99.7	99.7	99.7
		Avg.	100.0	99.7	99.5	99.5	99.5
Crafco SS 444	C	1	100.0	99.8	99.8	99.8	99.8
		2	100.0	99.7	99.4	99.3	99.2
		Avg.	100.0	99.7	99.6	99.5	99.5
Crafco 903-SL	C	1	100.0	99.5	98.9	98.4	98.4
		2	100.0	99.2	98.4	98.0	97.9
		Avg.	100.0	99.4	98.7	98.2	98.1
Dow 888	C	1	100.0	99.5	99.3	99.1	99.0
		2	100.0	99.5	99.1	99.0	98.9
		Avg.	100.0	99.5	99.2	99.1	99.0
Dow 888-SL	C	1	100.0	99.5	99.0	98.8	98.7
		2	100.0	99.1	98.0	97.8	97.7
		Avg.	100.0	99.3	98.5	98.3	98.2
Dow 890-SL	A	1	100.0	99.7	99.4	99.3	99.2
		2	100.0	98.8	97.6	97.5	97.4
		Avg.	100.0	99.2	98.5	98.4	98.3
Dow 890-SL	B	1	100.0	99.8	99.4	99.2	99.1
		2	100.0	99.5	98.5	98.5	98.4
		Avg.	100.0	99.7	99.0	98.8	98.7
Dow 890-SL	C	1	100.0	99.8	99.8	99.7	99.7
		2	100.0	99.6	98.8	98.7	98.6
		Avg.	100.0	99.7	99.3	99.2	99.1
D.S. Brown V-687	C	1	100.0	99.8	99.7	99.5	99.5
		2	100.0	99.7	99.6	99.6	99.4
		Avg.	100.0	99.7	99.6	99.6	99.5
Mobay 960-SL	C	1	100.0	97.7	97.1	96.6	96.2
		2	100.0	99.0	98.3	98.2	98.0
		Avg.	100.0	98.4	97.7	97.4	97.1
Watson Bowman 687	C	1	100.0	99.9	99.9	99.9	99.8
Watson Bowman 812	C	2	100.0	100.0	100.0	99.9	99.9
No Seal	A	1	100.0	99.8	99.5	99.4	99.2
		2	100.0	99.5	99.1	99.0	99.0
		Avg.	100.0	99.7	99.3	99.2	99.1

Table C-6. Twist effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
D.S. Brown V-687	C	1	100	100	100	100	100
		2	100	100	100	100	100
		Avg.	100	100	100	100	100
Watson Bowman 687	C	1	100	100	100	100	100
Watson Bowman 812	C	2	100	100	100	100	100

Table C-7. Compression set effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Compression set effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
D.S. Brown V-687	C	1	100.0	92.9	87.0	80.8	78.8
		2	100.0	98.3	93.8	93.2	91.6
		Avg.	100.0	95.6	90.4	87.0	85.2
Watson Bowman 687	C	1	100.0	99.5	98.8	96.6	94.7
Watson Bowman 812	C	2	100.0	100.0	98.1	95.4	95.0

Table C-8. Gap effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
D.S. Brown V-687	C	1	100.0	100.0	54.6	48.5	48.2
		2	100.0	100.0	47.7	43.1	41.8
		Avg.	100.0	100.0	51.1	45.8	45.0
Watson Bowman 687	C	1	100.0	100.0	96.8	94.6	92.7
Watson Bowman 812	C	2	100.0	100.0	98.8	98.1	95.3

Table C-9. Transverse joint seal performance at Campo, Colorado test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Crafco 902	A	1	99.9	99.7	99.3	97.2	98.9	94.9
Crafco 902	A	2	98.5	99.7	98.3	97.6	99.1	96.2
		Avg.	99.2	99.7	98.8	97.4	99.0	95.6
Crafco 902	B	1	97.1	99.9	99.3	96.1	98.7	97.8
Crafco 902	B	2	98.5	99.8	97.5	96.8	99.0	95.3
		Avg.	97.8	99.9	98.4	96.4	98.8	96.5
Crafco 902	C	1	93.3	100.0	99.7	97.3	99.1	98.8
Crafco 902	C	2	98.0	99.9	99.8	96.5	99.1	98.9
		Avg.	95.7	100.0	99.8	96.9	99.1	98.8
Crafco 902	G	1	98.1	100.0	97.9	98.8	99.2	97.1
Crafco 902	G	2	96.4	99.9	96.0	99.6	99.6	95.0
		Avg.	97.2	99.9	96.9	99.2	99.4	96.0
Crafco 903-SL	A	1	44.0	74.0	100.0	97.7	98.9	72.9
Crafco 903-SL	A	2	91.4	99.5	99.9	95.3	98.4	97.6
		Avg.	67.7	86.8	99.9	96.5	98.6	85.3
Crafco 903-SL	B	1	78.9	98.8	100.0	98.4	98.6	97.5
Crafco 903-SL	B	2	94.0	99.4	99.9	96.3	98.6	97.9
		Avg.	86.5	99.1	100.0	97.3	98.6	97.7
Crafco 903-SL	C	1	74.2	99.8	100.0	98.2	99.4	99.2
Crafco 903-SL	C	2	95.8	99.9	100.0	96.2	98.8	98.7
		Avg.	85.0	99.9	100.0	97.2	99.1	99.0
No Seal	A	1	100.0	100.0	100.0	92.8	97.2	97.2
No Seal	A	2	100.0	100.0	100.0	92.4	99.0	99.0
		Avg.	100.0	100.0	100.0	92.6	98.1	98.1

Table C-10. Overall transverse joint seal effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
Crafco 902	A	1	100.0	99.8	98.7	97.9
		2	100.0	99.8	98.1	97.1
		Avg.	100.0	99.8	98.4	97.5
Crafco 902	B	1	100.0	99.2	98.3	97.9
		2	100.0	98.9	96.5	96.2
		Avg.	100.0	99.1	97.4	97.1
Crafco 902	C	1	100.0	99.7	99.2	98.8
		2	100.0	99.8	99.3	98.9
		Avg.	100.0	99.7	99.2	98.8
Crafco 902	G	1	100.0	99.0	97.4	97.1
		2	100.0	99.9	96.4	95.4
		Avg.	100.0	99.4	96.9	96.3
Crafco 903-SL	A	1	100.0	99.8	99.0	72.9
		2	100.0	99.8	98.7	97.8
		Avg.	100.0	99.8	98.8	85.4
Crafco 903-SL	B	1	100.0	99.2	98.3	97.5
		2	100.0	99.5	99.0	97.9
		Avg.	100.0	99.4	98.6	97.7
Crafco 903-SL	C	1	100.0	99.8	99.6	99.2
		2	100.0	99.7	99.1	98.7
		Avg.	100.0	99.7	99.3	99.0
D.S. Brown E-437H	B	1	100.0	81.7	66.6	63.2
No Seal	A	1	100.0	98.5	98.1	97.2
		2	100.0	99.3	99.1	99.0
		Avg.	100.0	98.9	98.6	98.1
D.S. Brown V-687	C	1	100.0	85.2	82.8	82.7
Crafco 902	C	1	100.0	99.8	99.2	98.5

Table C-11. Adhesion effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
Crafco 902	A	1	100.0	99.9	99.9	99.7
		2	100.0	100.0	100.0	99.7
		Avg.	100.0	99.9	100.0	99.7
Crafco 902	B	1	100.0	99.9	99.9	99.9
		2	100.0	100.0	99.9	99.8
		Avg.	100.0	99.9	99.9	99.9
Crafco 902	C	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	99.9
		Avg.	100.0	100.0	100.0	100.0
Crafco 902	G	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	99.9
		Avg.	100.0	100.0	100.0	99.9
Crafco 903-SL	A	1	100.0	99.9	99.5	74.0
		2	100.0	99.9	99.9	99.5
		Avg.	100.0	99.9	99.7	86.8
Crafco 903-SL	B	1	100.0	99.9	99.7	98.8
		2	100.0	100.0	99.9	99.4
		Avg.	100.0	100.0	99.8	99.1
Crafco 903-SL	C	1	100.0	100.0	100.0	99.8
		2	100.0	100.0	99.9	99.9
		Avg.	100.0	100.0	100.0	99.9
D.S. Brown E-437H	B	1	100.0	100.0	100.0	100.0
No Seal	A	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0
Crafco 902	C	1	100.0	100.0	100.0	99.8

Table C-12. Cohesion effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
Crafco 902	A	1	100.0	99.9	99.3	99.3
		2	100.0	99.9	98.6	98.3
		Avg.	100.0	99.9	99.0	98.8
Crafco 902	B	1	100.0	99.9	99.4	99.3
		2	100.0	99.2	97.3	97.5
		Avg.	100.0	99.5	98.4	98.4
Crafco 902	C	1	100.0	99.9	99.7	99.7
		2	100.0	100.0	99.8	99.8
		Avg.	100.0	99.9	99.8	99.8
Crafco 902	G	1	100.0	99.4	98.1	97.9
		2	100.0	100.0	96.8	96.0
		Avg.	100.0	99.7	97.4	96.9
Crafco 903-SL	A	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	99.9	99.9
		Avg.	100.0	100.0	99.9	99.9
Crafco 903-SL	B	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	99.9
		Avg.	100.0	100.0	100.0	100.0
Crafco 903-SL	C	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0
D.S. Brown E-437H	B	1	100.0	100.0	100.0	100.0
No Seal	A	1	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0
Crafco 902	C	1	100.0	100.0	99.6	99.5

Table C-13. Spall effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
Crafco 902	A	1	100.0	100.0	99.5	98.9
		2	100.0	99.9	99.5	99.1
		Avg.	100.0	100.0	99.5	99.0
Crafco 902	B	1	100.0	99.5	99.0	98.7
		2	100.0	99.7	99.2	99.0
		Avg.	100.0	99.6	99.1	98.8
Crafco 902	C	1	100.0	99.8	99.5	99.1
		2	100.0	99.8	99.5	99.1
		Avg.	100.0	99.8	99.5	99.1
Crafco 902	G	1	100.0	99.6	99.3	99.2
		2	100.0	99.9	99.6	99.6
		Avg.	100.0	99.7	99.4	99.4
Crafco 903-SL	A	1	100.0	99.9	99.5	98.9
		2	100.0	99.9	98.9	98.4
		Avg.	100.0	99.9	99.2	98.6
Crafco 903-SL	B	1	100.0	99.3	98.6	98.6
		2	100.0	99.5	99.0	98.6
		Avg.	100.0	99.4	98.8	98.6
Crafco 903-SL	C	1	100.0	99.8	99.6	99.4
		2	100.0	99.7	99.1	98.8
		Avg.	100.0	99.7	99.4	99.1
D.S. Brown E-437H	B	1	100.0	100.0	99.8	99.5
No Seal	A	1	100.0	98.5	98.1	97.2
		2	100.0	99.3	99.1	99.0
		Avg.	100.0	98.9	98.6	98.1
D.S. Brown V-687	C	1	100.0	99.9	99.3	99.2
Crafco 902	C	1	100.0	99.8	99.6	99.2

Table C-14. Twist effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
D.S. Brown E-437H	B	1	100.0	97.1	95.9	96.4
D.S. Brown V-687	C	1	100.0	88.3	88.3	88.3

Table C-15. Compression set effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Comp. set effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
D.S. Brown E-437H	B	1	100.0	93.9	79.2	74.8
D.S. Brown V-687	C	1	100.0	100.0	98.1	98.1

Table C-16. Gap effectiveness at Campo, Colorado test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length			
			0 months	6 months	13 months	25 months
D.S. Brown E-437H	B	1	100.0	93.8	96.5	97.8
D.S. Brown V-687	C	1	100.0	99.9	100.0	100.0

Table C-17. Transverse joint seal performance summary at Wells, Nevada test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Crafco 902	C	1	98.0	99.2	99.0	88.1	85.4	83.7
Crafco 902	C	2	99.7	99.7	99.1	84.7	86.0	84.9
		Avg.	98.8	99.5	99.1	86.4	85.7	84.3
Crafco 903-SL	C	1	92.5	98.7	99.8	86.9	86.0	84.4
Crafco 903-SL	C	2	99.8	99.5	99.6	87.1	90.7	89.8
		Avg.	96.0	99.0	99.7	87.0	88.2	87.0
Dow 888	C	1	98.0	99.3	99.9	87.0	95.7	94.9
Dow 888	C	2	99.4	99.9	99.7	84.2	94.2	93.8
		Avg.	98.8	99.7	99.8	85.4	94.8	94.3
Dow 888	C	3	97.1	96.9	99.9	85.7	82.4	79.2
Dow 888	C	4	97.2	99.2	99.7	81.0	84.8	83.7
Dow 888-SL	C	1	98.5	98.5	100.0	90.2	91.8	90.3
Dow 888-SL	C	2	97.2	97.4	99.9	91.9	92.6	89.9
		Avg.	97.8	97.9	100.0	91.1	92.2	90.1
Dow 890-SL	C	1	91.6	97.4	100.0	92.4	89.7	87.1
Dow 890-SL	C	2	76.5	97.8	100.0	89.6	93.3	91.1
		Avg.	83.2	97.6	100.0	90.8	91.7	89.3
Mobay 960	C	1	96.1	99.3	99.7	81.5	87.3	86.3
Mobay 960	C	2	99.2	99.7	99.7	85.3	85.6	84.9
		Avg.	97.7	99.5	99.7	83.5	86.4	85.6
Polyethylene	F	1	100.0	100.0	0.0	94.9	94.2	0.0
Unsealed	C	1	100.0	100.0	100.0	95.8	90.8	90.8

Table C-18. Overall transverse joint seal effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	96.1	92.0	86.0	83.7
		2	100.0	97.2	94.5	88.8	84.9
		Avg.	100.0	96.7	93.3	87.4	84.3
Crafco 903-SL	C	1	100.0	96.3	94.9	89.1	84.4
		2	100.0	97.4	95.7	91.7	89.8
		Avg.	100.0	96.8	95.3	90.4	87.1
Dow 888	C	1	100.0	99.2	97.7	95.2	94.9
		2	100.0	98.4	98.1	92.8	93.8
		Avg.	100.0	98.8	97.9	94.0	94.3
Dow 888	C	1	100.0	95.0	94.4	86.2	83.7
Dow 888	C	1	100.0	96.8	95.9	83.3	79.2
Dow 888-SL	C	1	100.0	98.4	96.9	92.1	90.3
		2	100.0	96.9	97.2	92.4	89.9
		Avg.	100.0	97.7	97.0	92.2	90.1
Dow 890-SL	C	1	100.0	98.9	98.5	91.8	87.1
		2	100.0	97.8	97.1	93.6	91.1
		Avg.	100.0	98.4	97.8	92.7	89.1
D.S. Brown V-812	D	1	100.0	96.3	73.8	51.7	46.1
		2	100.0	97.8	73.3	36.7	24.7
		Avg.	100.0	97.0	73.5	44.2	35.4
Mobay 960	C	1	100.0	97.9	94.1	88.7	86.3
		2	100.0	96.9	92.8	88.0	84.9
		Avg.	100.0	97.4	93.5	88.4	85.6
No Seal	C	1	100.0	100.0	93.3	91.3	90.8
Polyethylene	F	1	100.0	0.0	0.0	0.0	0.0

Table C-19. Adhesion effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	100.0	99.6	99.5	99.2
		2	100.0	100.0	99.9	99.8	99.7
		Avg.	100.0	100.0	99.7	99.7	99.5
Crafco 903-SL	C	1	100.0	99.8	99.3	99.2	98.7
		2	100.0	100.0	99.8	99.9	99.5
		Avg.	100.0	99.9	99.5	99.5	99.1
Dow 888	C	1	100.0	100.0	99.9	99.4	99.2
		2	100.0	100.0	99.9	99.1	99.9
		Avg.	100.0	100.0	99.9	99.3	99.6
Dow 888	C	1	100.0	99.6	99.7	97.8	96.5
		1	100.0	100.0	100.0	99.5	99.2
Dow 888-SL	C	1	100.0	100.0	99.7	99.2	98.5
		2	100.0	100.0	99.8	99.3	97.4
		Avg.	100.0	100.0	99.8	99.3	97.9
Dow 890-SL	C	1	100.0	99.9	99.7	99.0	97.8
		2	100.0	99.9	99.7	99.5	97.8
		Avg.	100.0	99.9	99.7	99.2	97.8
D.S. Brown V-812	D	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	99.9	99.5	99.3	99.2
		2	100.0	100.0	99.9	99.9	99.7
		Avg.	100.0	99.9	99.7	99.6	99.4
No Seal	C	1	100.0	100.0	100.0	100.0	100.0
Polyethylene	F	1	100.0	100.0	100.0	100.0	100.0

Table C-20. Cohesion effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	99.7	99.3	99.1	99.0
		2	100.0	99.8	99.2	99.3	99.1
		Avg.	100.0	99.8	99.3	99.2	99.1
Crafco 903-SL	C	1	100.0	100.0	99.9	99.8	99.8
		2	100.0	100.0	99.9	99.7	99.7
		Avg.	100.0	100.0	99.9	99.8	99.7
Dow 888	C	1	100.0	100.0	100.0	99.7	99.7
		2	100.0	100.0	100.0	99.7	99.7
		Avg.	100.0	100.0	100.0	99.7	99.7
Dow 888	C	1	100.0	95.7	95.2	99.9	95.9
		1	100.0	100.0	99.9	99.7	99.7
Dow 888-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	99.9	99.9	99.9	99.9
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	C	1	100.0	100.0	100.0	99.9	99.9
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
D.S. Brown V-812	D	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	100.0	99.7	99.8	99.7
		2	100.0	100.0	99.9	99.7	99.7
		Avg.	100.0	100.0	99.8	99.8	99.7
No Seal	C	1	100.0	100.0	100.0	100.0	100.0
Polyethylene	F	1	100.0	0.0	0.0	0.0	0.0

Table C-21. Spall effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	96.4	93.1	87.4	85.4
		2	100.0	97.4	95.4	89.7	86.0
		Avg.	100.0	96.9	94.3	88.5	85.7
Crafco 903-SL	C	1	100.0	96.5	95.7	90.1	86.0
		2	100.0	97.2	95.6	91.9	90.6
		Avg.	100.0	96.8	95.6	91.0	88.3
Dow 888	C	1	100.0	99.2	97.9	95.9	95.7
		2	100.0	98.4	98.2	94.9	94.2
		Avg.	100.0	98.8	98.1	95.4	94.9
Dow 888	C	1	100.0	97.1	96.2	87.2	84.2
		1	100.0	95.0	95.2	87.0	84.8
Dow 888-SL	C	1	100.0	98.4	97.2	92.8	91.8
		2	100.0	97.0	97.4	93.1	92.6
		Avg.	100.0	97.7	97.3	93.0	92.2
Dow 890-SL	C	1	100.0	97.9	97.8	92.0	88.1
		2	100.0	97.9	97.4	94.1	93.3
		Avg.	100.0	97.9	97.6	93.1	90.7
D.S. Brown V-812	D	1	100.0	99.2	98.7	97.9	97.7
		2	100.0	99.0	98.7	98.4	97.9
		Avg.	100.0	99.1	98.7	98.2	97.8
Mobay 960	C	1	100.0	97.7	94.7	89.7	87.4
		2	100.0	96.9	93.1	88.3	85.6
		Avg.	100.0	97.3	93.9	89.0	86.5
No Seal	C	1	100.0	100.0	93.3	91.3	90.8
Polyethylene	F	1	100.0	99.8	96.3	94.8	94.4

Table C-22. Twist effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
D.S. Brown V-812	D	1	100.0	97.2	88.2	88.0	87.6
		2	100.0	98.8	96.1	95.0	95.1
		Avg.	100.0	98.0	92.2	91.5	91.4

Table C-23. Compression set effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Comp. set effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
D.S. Brown V-812	D	1	100.0	100.0	94.3	77.1	71.0
		2	100.0	100.0	80.3	45.1	42.4
		Avg.	100.0	100.0	87.3	61.1	56.7

Table C-24. Gap effectiveness at Wells, Nevada test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
D.S. Brown V-812	D	1	100.0	100.0	100.0	95.6	90.1
		2	100.0	100.0	100.0	98.6	89.4
		Avg.	100.0	100.0	100.0	97.1	89.7

Table C-25. Transverse joint seal performance summary at Tremonton, Utah test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Dow 888-SL	C	1	99.6	64.1	100.0	96.9	92.8	56.9
Dow 888-SL	C	2	99.8	46.5	99.9	98.3	94.3	40.7
		Avg.	99.7	55.3	100.0	97.6	93.5	48.8
Dow 890-SL	A	1	99.5	84.7	93.9	92.6	96.4	74.9
Dow 890-SL	A	2	99.3	91.3	98.3	94.0	95.9	85.5
		Avg.	99.4	88.0	96.1	93.3	96.2	80.2
Dow 890-SL	E	1	96.9	89.2	99.2	92.2	92.5	80.8
Koch 9005	C	1	60.6	9.3	96.9	97.1	97.8	4.1
Koch 9005	C	2	55.4	18.5	98.6	96.2	97.3	14.4
		Avg.	58.0	13.9	97.7	96.7	97.6	9.2
Koch 9012	C	1	81.8	33.8	65.4	96.1	98.1	0.0
Koch 9012	C	2	89.4	16.6	84.5	97.9	99.1	0.2
		Avg.	85.6	25.2	74.9	97.0	98.6	0.0
Mobay 960	C	1	96.6	99.9	99.8	91.7	94.2	93.9
Mobay 960	C	2	97.7	99.6	99.8	91.6	94.5	93.9
		Avg.	97.1	99.7	99.8	91.6	94.4	93.9
Mobay 960	C	1	97.9	99.7	100.0	94.4	95.8	95.5
Mobay 960	C	2	89.4	99.0	99.9	90.8	93.0	92.0
		Avg.	93.7	99.4	100.0	92.6	94.4	93.8
Roshek	E	1	100.0	92.5	27.7	97.3	96.7	16.8
No Seal	A	1	100.0	100.0	100.0	95.0	96.3	96.3
No Seal	A	2	100.0	100.0	100.0	95.1	98.3	98.3
	A	Avg.	100.0	100.0	100.0	95.1	97.3	97.3
No Seal	E	1	100.0	100.0	100.0	88.9	90.0	90.0

Table C-26. Overall transverse joint seal effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Dow 888-SL	C	1	100.0	94.6	74.8	71.3	56.9
		2	100.0	92.2	67.3	52.3	40.7
		Avg.	100.0	93.4	71.1	61.8	48.8
Dow 890-SL	A	1	100.0	98.2	92.9	89.2	74.9
		2	100.0	97.9	93.4	89.7	85.5
		Avg.	100.0	98.1	93.2	89.5	80.2
Dow 890-SL	E	1	100.0	88.6	86.6	83.7	80.9
Koch 9005	C	1	100.0	72.8	36.3	17.5	4.5
		2	100.0	59.7	29.2	20.7	15.2
		Avg.	100.0	66.3	32.8	19.1	9.9
Koch 9012	C	1	100.0	70.3	32.1	12.2	0.2
		2	100.0	36.8	9.7	5.0	0.9
		Avg.	100.0	53.5	20.9	8.6	0.5
Kold Seal Neo Loop	B	1	100.0	90.4	0.0	0.0	0.0
		2	100.0	74.3	8.7	5.5	3.9
		Avg.	100.0	82.3	4.3	2.7	1.9
Mobay 960	C	1	100.0	99.2	98.4	96.8	95.5
		2	100.0	98.1	96.2	93.9	92.0
		Avg.	100.0	98.7	97.3	95.3	93.8
Mobay 960	C	1	100.0	97.2	96.1	95.1	93.9
		2	100.0	98.1	96.8	95.5	93.9
		Avg.	100.0	97.7	96.4	95.3	93.9
Roshek	E	1	100.0	36.6	28.5	18.3	17.7
Esco PV 687	C	1	100.0	79.6	37.9	37.4	37.1
		2	100.0	88.5	45.9	29.0	26.1
		Avg.	100.0	84.1	41.9	33.2	31.6
No Seal	A	1	100.0	97.3	96.8	96.5	96.3
		2	100.0	98.8	98.5	98.4	98.3
		Avg.	100.0	98.1	97.6	97.4	97.3
No Seal	E	1	100.0	92.9	90.7	90.4	90.0

Table C-27. Adhesion effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Dow 888-SL	C	1	100.0	97.5	79.3	77.7	64.1
		2	100.0	94.2	70.8	57.2	46.5
		Avg.	100.0	95.8	75.1	67.4	55.3
Dow 890-SL	A	1	100.0	99.9	99.5	98.1	84.7
		2	100.0	99.2	97.7	95.0	91.3
		Avg.	100.0	99.6	98.6	96.5	88.0
Dow 890-SL	E	1	100.0	96.2	93.3	91.1	89.2
Koch 9005	C	1	100.0	75.1	39.1	20.7	9.3
		2	100.0	63.1	32.0	23.8	18.5
		Avg.	100.0	69.1	35.5	22.2	13.9
Koch 9012	C	1	100.0	75.9	35.4	24.0	33.8
		2	100.0	37.0	11.9	8.2	16.6
		Avg.	100.0	56.4	23.7	16.1	25.2
Kold Seal Neo Loop	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	100.0	99.9	99.9	99.7
		2	100.0	100.0	99.8	99.7	99.0
		Avg.	100.0	100.0	99.9	99.8	99.4
Mobay 960	C	1	100.0	100.0	99.8	99.9	99.9
		2	100.0	100.0	99.9	99.9	99.6
		Avg.	100.0	100.0	99.9	99.9	99.7
Roshek	C	1	100.0	92.4	93.6	93.0	92.5
Esco PV 687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	E	1	100.0	100.0	100.0	100.0	100.0

Table C-28. Cohesion effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Dow 888-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	99.9	99.9	99.9
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	A	1	100.0	99.5	96.1	94.4	93.9
		2	100.0	99.9	97.8	98.6	98.3
		Avg.	100.0	99.7	97.0	96.5	96.1
Dow 890-SL	E	1	100.0	100.0	100.0	99.6	99.2
Koch 9005	C	1	100.0	99.2	99.3	98.8	96.9
		2	100.0	97.5	99.0	98.7	98.6
		Avg.	100.0	98.4	99.1	98.8	97.7
Koch 9012	C	1	100.0	100.0	100.0	91.0	65.4
		2	100.0	100.0	93.7	88.8	84.5
		Avg.	100.0	100.0	96.8	89.9	74.9
Kold Seal Neo Loop	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	99.9	99.9	99.9
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	100.0	100.0	99.9	99.8
		2	100.0	100.0	100.0	99.9	99.8
		Avg.	100.0	100.0	100.0	99.9	99.8
Roshek	C	1	100.0	43.8	36.6	27.9	27.7
Esco PV 687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	E	1	100.0	100.0	100.0	100.0	100.0

Table C-29. Spall effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Dow 888-SL	C	1	100.0	97.2	95.5	93.6	92.8
		2	100.0	98.0	96.5	95.2	94.3
		Avg.	100.0	97.6	96.0	94.4	93.5
Dow 890-SL	A	1	100.0	98.8	97.6	96.9	96.4
		2	100.0	98.7	97.9	97.1	95.9
		Avg.	100.0	98.8	97.7	97.0	96.2
Dow 890-SL	E	1	100.0	94.7	93.3	93.1	92.5
Koch 9005	C	1	100.0	98.5	97.9	97.8	97.8
		2	100.0	98.4	97.9	97.6	97.3
		Avg.	100.0	98.4	97.9	97.7	97.6
Koch 9012	C	1	100.0	99.0	98.5	98.3	98.1
		2	100.0	99.8	99.5	99.4	99.1
		Avg.	100.0	99.4	99.0	98.8	98.6
Kold Seal Neo Loop	B	1	100.0	99.9	98.2	98.1	97.7
		2	100.0	99.7	98.5	98.4	98.3
		Avg.	100.0	99.8	98.4	98.2	98.0
Mobay 960	C	1	100.0	99.2	98.5	96.9	95.8
		2	100.0	98.1	96.5	94.3	93.0
		Avg.	100.0	98.7	97.5	95.6	94.4
Mobay 960	C	1	100.0	97.2	96.3	95.4	94.2
		2	100.0	98.1	96.9	95.7	94.5
		Avg.	100.0	97.7	96.6	95.5	94.4
Roshek	C	1	100.0	98.1	97.3	96.9	96.7
Esco PV 687	C	1	100.0	99.6	99.0	99.0	98.9
		2	100.0	98.0	95.9	95.0	94.6
		Avg.	100.0	98.8	97.5	97.0	96.7
No Seal	A	1	100.0	97.3	96.8	96.5	96.3
		2	100.0	98.8	98.5	98.4	98.3
		Avg.	100.0	98.1	97.6	97.4	97.3
No Seal	E	1	100.0	91.3	89.2	89.0	88.7

Table C-30. Twist effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Kold Seal Neo Loop	B	1	100.0	99.8	99.8	99.5	99.7
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	99.9	99.9	99.7	99.9
Esco PV 687	C	1	100.0	79.9	68.1	79.3	83.5
		2	100.0	90.5	87.0	95.1	95.3
		Avg.	100.0	85.2	77.5	87.2	89.4

Table C-31. Compression set effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Compression set effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Kold Seal Neo Loop	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Esco PV 687	C	1	100.0	100.0	99.5	100.0	93.7
		2	100.0	100.0	100.0	83.9	74.1
		Avg.	100.0	100.0	99.7	91.9	83.9

Table C-32. Gap effectiveness at Tremonton, Utah test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length				
			0 months	47 months	61 months	73 months	85 months
Kold Seal Neo Loop	B	1	100.0	90.7	25.7	0.0	0.0
		2	100.0	74.6	58.1	18.5	6.8
		Avg.	100.0	82.6	41.9	9.3	3.4
Esco PV 687	C	1	100.0	100.0	60.6	54.7	44.4
		2	100.0	100.0	68.8	59.4	57.5
		Avg.	100.0	100.0	64.7	57.0	51.0

Table C-33. Transverse joint seal performance summary at Salt Lake City, Utah test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Crafco RS 221	C	1	37.9	27.5	36.2	3.0	0.9	64.7
Crafco RS 221	C	2	47.0	48.4	0.1	4.5	1.9	50.5
		Avg.	42.5	38.0	18.2	3.7	1.4	57.6
Dow 888	C	1	0.1	28.6	0.1	8.3	6.9	35.8
Dow 888	C	2	0.9	1.6	0.1	9.8	7.3	8.9
		Avg.	0.5	15.1	0.1	9.1	7.1	22.3
Dow 888-SL	C	1	13.4	29.9	0.0	6.2	8.1	38.0
Dow 888-SL	C	2	4.9	10.2	0.0	7.9	6.7	16.9
		Avg.	9.1	20.0	0.0	7.0	7.4	27.4
Dow 890-SL	A	1	17.7	66.1	0.0	4.2	4.1	70.1
Dow 890-SL	A	2	18.8	22.9	0.5	8.0	5.5	28.9
		Avg.	18.2	44.5	0.3	6.1	4.8	49.5
Dow 890-SL	E	2	53.9	30.7	0.3	9.7	8.7	39.8
Koch 9012	C	1	4.6	11.5	0.0	2.8	1.7	13.2
Koch 9012	C	2	7.8	32.2	45.4	2.5	1.2	78.8
		Avg.	6.2	21.8	22.7	2.7	1.4	46.0
Koch 9050-SL	C	1	0.5	20.3	48.3	6.1	5.3	73.8
Koch 9050-SL	C	2	0.1	42.0	43.6	4.6	4.1	89.8
		Avg.	0.3	31.1	46.0	5.4	4.7	81.8
No Seal	A	1	0.0	0.0	0.0	5.9	6.8	6.8
No Seal	A	2	0.0	0.0	0.0	10.1	6.4	6.4
		Avg.	0.0	0.0	0.0	8.0	6.6	6.6
No Seal	E	2	0.0	0.0	0.0	11.3	8.9	8.9

Table C-34. Overall transverse joint seal effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
Crafco RS 221	C	1	100.0	99.0	77.0	55.0	35.0
		2	100.0	93.0	82.0	73.0	50.0
		Avg.	100.0	96.0	79.5	64.0	42.5
Dow 888	C	1	100.0	97.0	89.0	73.0	64.0
		2	100.0	98.0	96.0	94.0	91.0
		Avg.	100.0	97.5	92.5	83.5	77.5
Dow 888-SL	C	1	100.0	91.0	82.0	74.0	62.0
		2	100.0	97.0	93.0	89.0	83.0
		Avg.	100.0	94.0	87.5	81.5	72.5
Dow 890-SL	A	1	100.0	65.0	40.0	34.0	30.0
		2	100.0	92.0	85.0	78.0	71.0
		Avg.	100.0	78.5	62.5	56.0	50.5
Dow 890-SL	E	1	100.0	91.0	81.0	69.0	60.0
D.S. Brown E-437H	B	1	100.0	97.0	31.0	28.0	26.0
		2	100.0	98.0	34.0	24.0	21.0
		Avg.	100.0	97.5	32.5	26.0	23.5
D.S. Brown V-687	C	1	100.0	98.0	82.0	73.0	61.0
		2	100.0	93.0	92.0	91.0	79.0
		Avg.	100.0	95.5	87.0	82.0	70.0
Koch 9012	C	1	100.0	99.0	95.0	92.0	87.0
		2	100.0	95.0	80.0	47.0	21.0
		Avg.	100.0	97.0	87.5	69.5	54.0
Koch 9050-SL	C	1	100.0	97.0	64.0	47.0	26.0
		2	100.0	58.0	33.0	16.0	10.0
		Avg.	100.0	77.5	48.5	31.5	18.0
No Seal	A	1	100.0	98.0	97.0	94.0	93.0
		2	100.0	97.0	95.0	95.0	94.0
		Avg.	100.0	97.5	96.0	94.5	93.5
No Seal	E	1	100.0	96.0	92.0	91.0	91.0

Table C-35. Adhesion effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
Crafco RS 221	C	1	100.0	99.4	79.4	83.2	72.5
		2	100.0	93.3	83.9	74.4	51.6
		Avg.	100.0	96.4	81.6	78.8	62.0
Dow 888	C	1	100.0	99.9	92.4	80.1	71.4
		2	100.0	99.9	99.6	99.4	98.4
		Avg.	100.0	99.9	96.0	89.8	84.9
Dow 888-SL	C	1	100.0	94.4	86.9	81.5	70.1
		2	100.0	99.3	95.1	93.2	89.8
		Avg.	100.0	96.9	91.0	87.4	80.0
Dow 890-SL	A	1	100.0	67.5	42.5	37.0	33.9
		2	100.0	93.5	87.7	81.8	77.1
		Avg.	100.0	80.5	65.1	59.4	55.5
Dow 890-SL	E	1	100.0	96.0	88.0	76.3	69.3
D.S. Brown E-437H	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Koch 9012	C	1	100.0	100.0	95.9	93.7	88.5
		2	100.0	94.9	80.5	60.6	67.8
		Avg.	100.0	97.5	88.2	77.1	78.2
Koch 9050-SL	C	1	100.0	99.1	90.6	87.7	79.7
		2	100.0	67.1	62.7	58.4	58.0
		Avg.	100.0	83.1	76.7	73.0	68.9
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	E	1	100.0	100.0	100.0	100.0	100.0

Table C-36. Cohesion effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
Crafco RS 221	C	1	100.0	100.0	98.3	72.6	63.8
		2	100.0	100.0	100.0	100.0	99.9
		Avg.	100.0	100.0	99.2	86.3	81.8
Dow 888	C	1	100.0	99.7	99.8	99.9	99.9
		2	100.0	100.0	100.0	99.9	99.9
		Avg.	100.0	99.8	99.9	99.9	99.9
Dow 888-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	99.9	99.5
		Avg.	100.0	100.0	100.0	100.0	99.7
Dow 890-SL	E	1	100.0	100.0	100.0	100.0	99.7
D.S. Brown E-437H	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Koch 9012	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	81.3	54.6
		Avg.	100.0	100.0	100.0	90.7	77.3
Koch 9050-SL	C	1	100.0	99.6	77.2	64.2	51.7
		2	100.0	92.3	72.6	60.8	56.4
		Avg.	100.0	95.9	74.9	62.5	54.0
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	E	1	100.0	100.0	100.0	100.0	100.0

Table C-37. Spall effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
Crafco RS 221	C	1	100.0	99.5	99.4	99.2	99.1
		2	100.0	99.3	98.6	98.4	98.1
		Avg.	100.0	99.4	99.0	98.8	98.6
Dow 888	C	1	100.0	97.7	96.7	93.8	93.1
		2	100.0	98.6	96.6	95.0	92.7
		Avg.	100.0	98.1	96.7	94.4	92.9
Dow 888-SL	C	1	100.0	96.9	94.8	92.9	91.9
		2	100.0	98.3	97.7	95.7	93.3
		Avg.	100.0	97.6	96.3	94.3	92.6
Dow 890-SL	A	1	100.0	97.9	97.3	96.6	95.9
		2	100.0	98.3	97.0	96.2	94.5
		Avg.	100.0	98.1	97.2	96.4	95.2
Dow 890-SL	E	1	100.0	95.0	93.5	92.4	91.3
D.S. Brown E-437H	B	1	100.0	96.9	96.1	95.4	95.3
		2	100.0	98.8	97.9	97.1	96.5
		Avg.	100.0	97.9	97.0	96.3	95.9
D.S. Brown V-687	C	1	100.0	98.5	97.7	97.7	97.5
		2	100.0	98.5	97.9	97.7	96.9
		Avg.	100.0	98.5	97.8	97.7	97.2
Koch 9012	C	1	100.0	99.0	98.7	98.4	98.3
		2	100.0	99.9	99.7	99.4	98.8
		Avg.	100.0	99.5	99.2	98.9	98.6
Koch 9050-SL	C	1	100.0	98.5	96.5	95.4	94.7
		2	100.0	98.8	97.8	96.5	95.9
		Avg.	100.0	98.6	97.1	95.9	95.3
No Seal	A	1	100.0	98.2	96.5	94.3	93.2
		2	100.0	97.1	95.1	94.6	93.6
		Avg.	100.0	97.7	95.8	94.4	93.4
No Seal	E	1	100.0	96.0	91.6	91.3	91.1

Table C-38. Twist effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
D.S. Brown E-437H	B	1	100.0	100.0	100.0	97.9	99.5
		2	100.0	98.7	88.7	88.5	89.4
		Avg.	100.0	99.4	94.4	93.2	94.4
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	94.8	95.0	94.9	94.9
		Avg.	100.0	97.4	97.5	97.5	97.5

Table C-39. Compression set effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Compression set effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
D.S. Brown E-437H	B	1	100.0	100.0	76.2	72.8	65.5
		2	100.0	100.0	72.1	50.5	48.2
		Avg.	100.0	100.0	74.1	61.6	56.8
D.S. Brown V-687	C	1	100.0	100.0	93.3	78.8	70.3
		2	100.0	100.0	100.0	99.5	88.9
		Avg.	100.0	100.0	96.7	89.1	79.6

Table C-40. Gap effectiveness at Salt Lake City, Utah test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length				
			0 months	25 months	39 months	51 months	63 months
D.S. Brown E-437H	B	1	100.0	100.0	58.5	63.0	66.0
		2	100.0	100.0	82.9	90.9	86.3
		Avg.	100.0	100.0	70.7	76.9	76.2
D.S. Brown V-687	C	1	100.0	100.0	92.2	97.6	92.6
		2	100.0	100.0	99.8	99.4	99.1
		Avg.	100.0	100.0	96.0	98.5	95.9

Table C-41. Transverse joint seal performance summary at Heber City, Utah test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Dow 888	C	1	100.0	26.2	99.9	90.9	96.3	22.4
Dow 888	C	2	100.0	34.0	99.3	89.8	76.2	9.4
		Avg.	100.0	30.1	99.6	90.3	86.2	15.9
Dow 888-SL	C	1	99.0	27.1	100.0	94.3	96.7	23.8
Dow 888-SL	C	2	99.7	36.2	100.0	94.2	78.4	14.6
		Avg.	99.3	31.7	100.0	94.2	87.6	19.2
Dow 890-SL	A	1	98.8	58.7	99.9	91.1	95.7	54.3
Dow 890-SL	A	2	100.0	21.2	100.0	92.0	89.1	10.3
		Avg.	99.4	40.0	100.0	91.6	92.4	32.3
Dow 890-SL	E	1	93.1	81.1	100.0	75.8	92.0	73.1
Dow 890-SL	E	2	60.2	88.4	96.8	81.9	77.5	62.6
		Avg.	76.0	84.9	98.3	79.0	84.5	67.6
Koch 9005	C	1	100.0	97.1	87.1	99.0	98.8	83.0
Koch 9005	C	2	27.6	19.5	99.7	91.8	96.2	15.5
		Avg.	63.8	58.3	93.4	95.4	97.5	49.2
Koch 9012	C	1	94.6	53.9	100.0	96.8	98.4	52.4
Koch 9012	C	2	73.8	37.0	99.8	95.5	98.8	35.6
		Avg.	84.2	45.5	99.9	96.2	98.6	44.0
Koch 9050-SL	C	1	100.0	5.4	94.3	93.8	99.7	0.0
Koch 9050-SL	C	2	100.0	72.9	33.3	91.2	94.6	0.8
		Avg.	100.0	39.1	63.8	92.5	97.1	0.1
No Seal	A	1	100.0	100.0	100.0	96.2	94.9	94.9
No Seal	A	2	100.0	99.6	100.0	88.7	85.6	85.2
		Avg.	100.0	99.8	100.0	92.4	90.2	90.0
No Seal	E	1	100.0	100.0	100.0	93.3	93.0	93.0
No Seal	E	2	100.0	100.0	100.0	93.1	94.3	94.3
		Avg.	100.0	100.0	100.0	93.2	93.7	93.7

Table C-42. Overall transverse joint seal effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
Dow 888	C	1	100.0	71.0	49.0	30.0	23.0
		2	100.0	66.0	37.0	22.0	13.0
		Avg.	100.0	68.5	43.0	26.0	18.0
Dow 888-SL	C	1	100.0	76.0	58.0	35.0	24.0
		2	100.0	76.0	43.0	28.0	16.0
		Avg.	100.0	76.0	50.5	31.5	20.0
Dow 890-SL	A	1	100.0	93.0	82.0	65.0	54.0
		2	100.0	73.0	38.0	25.0	11.0
		Avg.	100.0	83.0	60.0	45.0	32.5
Dow 890-SL	E	1	100.0	93.0	83.0	77.0	73.0
		2	100.0	74.0	74.0	72.0	62.0
		Avg.	100.0	83.5	78.5	74.5	67.5
D.S. Brown E-437H	B	1	100.0	100.0	86.0	85.0	78.0
		2	100.0	94.0	78.0	72.0	66.0
		Avg.	100.0	97.0	82.0	78.5	72.0
D.S. Brown V-687	C	1	100.0	99.0	93.0	93.0	92.0
		2	100.0	98.0	96.0	94.0	93.0
		Avg.	100.0	98.5	94.5	93.5	92.5
Koch 9005	C	1	100.0	99.0	99.0	98.0	83.0
		2	100.0	99.0	70.0	27.0	16.0
		Avg.	100.0	99.0	84.5	62.5	49.5
Koch 9012	C	1	100.0	98.0	89.0	68.0	52.0
		2	100.0	100.0	81.0	67.0	36.0
		Avg.	100.0	99.0	85.0	67.5	44.0
Koch 9050-SL	C	1	100.0	3.0	0.0	0.0	0.0
		2	100.0	83.0	13.0	7.0	3.0
		Avg.	100.0	43.0	6.5	3.5	1.5
No Seal	A	1	100.0	99.0	96.0	95.0	95.0
		2	100.0	92.0	87.0	86.0	85.0
		Avg.	100.0	95.5	91.5	90.5	90.0
No Seal	E	1	100.0	97.0	95.0	94.0	93.0
		2	100.0	97.0	96.0	95.0	94.0
		Avg.	100.0	97.0	95.5	94.5	93.5

Table C-43. Adhesion effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
Dow 888	C	1	100.0	71.8	50.8	32.9	26.2
		2	100.0	71.2	55.0	44.6	34.0
		Avg.	100.0	71.5	52.9	38.8	30.1
Dow 888-SL	C	1	100.0	78.1	60.0	37.6	27.1
		2	100.0	81.0	60.0	47.8	36.2
		Avg.	100.0	79.5	60.0	42.7	31.7
Dow 890-SL	A	1	100.0	93.7	83.0	68.7	58.7
		2	100.0	76.9	46.3	35.3	21.2
		Avg.	100.0	85.3	64.7	52.0	40.0
Dow 890-SL	E	1	100.0	90.3	89.6	84.9	82.6
		2	100.0	78.0	97.5	96.2	88.4
		Avg.	100.0	84.1	93.5	90.5	85.5
D.S. Brown E-437H	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Koch 9005	C	1	100.0	100.0	100.0	99.9	97.1
		2	100.0	99.3	71.9	30.0	19.5
		Avg.	100.0	99.7	86.0	64.9	58.3
Koch 9012	C	1	100.0	99.2	90.0	72.9	53.9
		2	100.0	99.9	83.0	68.5	37.0
		Avg.	100.0	99.5	86.5	70.7	45.5
Koch 9050-SL	C	1	100.0	4.5	4.6	5.1	5.4
		2	100.0	84.7	77.9	75.6	72.9
		Avg.	100.0	44.6	41.3	40.3	39.1
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	99.6
		Avg.	100.0	100.0	100.0	100.0	99.8
No Seal	E	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0

Table C-44. Cohesion effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
Dow 888	C	1	100.0	100.0	99.9	99.9	99.9
		2	100.0	99.2	98.2	99.4	99.3
		Avg.	100.0	99.6	99.1	99.7	99.6
Dow 888-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	A	1	100.0	100.0	100.0	99.9	99.9
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 890-SL	E	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	97.7	97.6	96.8
		Avg.	100.0	100.0	98.9	98.8	98.4
D.S. Brown E-437H	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Koch 9005	C	1	100.0	99.9	99.8	99.4	87.1
		2	100.0	99.8	99.7	100.0	99.7
		Avg.	100.0	99.9	99.7	99.7	93.4
Koch 9012	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	98.6	99.8	99.8
		Avg.	100.0	100.0	99.3	99.9	99.9
Koch 9050-SL	C	1	100.0	98.2	95.0	94.2	94.3
		2	100.0	99.9	38.1	34.9	33.3
		Avg.	100.0	99.1	66.6	64.6	63.8
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
No Seal	E	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0

Table C-45. Spall effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
Dow 888	C	1	100.0	99.5	98.8	97.6	96.3
		2	100.0	95.9	83.2	77.2	76.2
		Avg.	100.0	97.7	91.0	87.4	86.2
Dow 888-SL	C	1	100.0	98.3	98.2	97.5	96.7
		2	100.0	95.4	83.4	79.9	78.4
		Avg.	100.0	96.8	90.8	88.7	87.6
Dow 890-SL	A	1	100.0	99.0	98.7	96.6	95.7
		2	100.0	95.8	91.5	90.0	89.1
		Avg.	100.0	97.4	95.1	93.3	92.4
Dow 890-SL	E	1	100.0	95.4	93.9	92.0	91.1
		2	100.0	84.3	79.0	78.0	77.5
		Avg.	100.0	89.8	86.4	85.0	84.3
D.S. Brown E-437H	B	1	100.0	99.7	99.5	98.9	98.4
		2	100.0	98.4	97.0	95.4	94.9
		Avg.	100.0	99.0	98.3	97.1	96.7
D.S. Brown V-687	C	1	100.0	99.9	99.9	99.4	98.8
		2	100.0	98.1	96.5	94.4	93.9
		Avg.	100.0	99.0	98.2	96.9	96.4
Koch 9005	C	1	100.0	99.6	99.4	99.0	98.8
		2	100.0	99.8	98.2	96.9	96.2
		Avg.	100.0	99.7	98.8	97.9	97.5
Koch 9012	C	1	100.0	99.2	99.1	98.6	98.4
		2	100.0	99.7	99.2	99.1	98.8
		Avg.	100.0	99.5	99.2	98.8	98.6
Koch 9050-SL	C	1	100.0	100.0	99.7	99.7	99.7
		2	100.0	98.1	97.0	96.3	94.6
		Avg.	100.0	99.0	98.4	98.0	97.1
No Seal	A	1	100.0	99.0	96.1	95.4	94.9
		2	100.0	91.9	87.0	86.1	85.6
		Avg.	100.0	95.4	91.6	90.8	90.2
No Seal	E	1	100.0	96.9	94.5	93.6	93.0
		2	100.0	97.4	95.7	95.0	94.3
		Avg.	100.0	97.1	95.1	94.3	93.7

Table C-46. Twist effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
D.S. Brown E-437H	B	1	100.0	100.0	99.9	99.9	100.0
		2	100.0	95.5	86.1	94.1	93.3
		Avg.	100.0	97.8	93.0	97.0	96.6
D.S. Brown V-687	C	1	100.0	99.0	98.3	98.5	98.8
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	99.5	99.2	99.2	99.4

Table C-47. Compression set effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Compression set effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
D.S. Brown E-437H	B	1	100.0	100.0	97.4	93.2	83.7
		2	100.0	100.0	95.6	86.2	82.0
		Avg.	100.0	100.0	96.5	89.7	82.8
D.S. Brown V-687	C	1	100.0	100.0	100.0	100.0	98.9
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	99.5

Table C-48. Gap effectiveness at Heber City, Utah test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length				
			0 months	36 months	49 months	61 months	73 months
D.S. Brown E-437H	B	1	100.0	100.0	87.3	99.7	99.0
		2	100.0	100.0	98.6	97.7	97.8
		Avg.	100.0	100.0	93.0	98.7	98.4
D.S. Brown V-687	C	1	100.0	100.0	99.4	99.5	99.7
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	99.7	99.8	99.9

Table C-49. Longitudinal joint seal performance summary at Mesa, Arizona test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Crafco RS 221	C	1	100.0	100.0	0.5	97.9	99.6	0.2
Crafco RS 221	C	2	43.8	45.7	99.3	97.3	98.9	43.9
		Avg.	72.2	73.1	49.4	97.6	99.3	21.8
Crafco SS 444	C	1	100.0	99.1	11.0	98.8	99.6	9.8
Crafco SS 444	C	2	88.0	99.5	98.2	96.6	100.0	97.6
		Avg.	94.1	99.3	54.1	97.7	99.8	53.2
Crafco 903-SL	C	1	98.9	100.0	99.1	96.4	99.1	98.1
Crafco 903-SL	C	2	98.0	99.8	100.0	93.1	98.9	98.7
		Avg.	98.4	99.9	99.5	94.8	99.0	98.4
Dow 888	C	1	100.0	98.9	99.8	93.0	99.3	98.0
Dow 888	C	2	100.0	100.0	100.0	92.9	96.7	96.7
		Avg.	100.0	99.5	99.9	92.9	98.0	97.3
Dow 888-SL	C	1	99.6	99.4	100.0	95.5	98.6	98.1
Dow 888-SL	C	2	98.0	97.0	99.6	86.3	97.2	93.9
		Avg.	98.8	98.2	99.8	90.8	97.9	95.9
Dow 890-SL	A	1	98.6	98.4	100.0	95.7	98.3	96.7
Dow 890-SL	A	2	96.0	97.6	98.9	96.6	95.5	92.0
		Avg.	97.3	98.0	99.4	96.2	96.8	94.3
Dow 890-SL	B	1	100.0	99.6	100.0	97.2	99.6	99.2
Dow 890-SL	B	2	99.8	100.0	100.0	98.6	98.8	98.8
		Avg.	99.9	99.8	100.0	97.9	99.1	99.0
Dow 890-SL	C	1	80.6	98.4	100.0	95.5	94.8	93.2
Dow 890-SL	C	2	98.6	99.1	100.0	97.2	99.8	98.9
		Avg.	90.0	98.8	100.0	96.4	97.4	96.2
Mobay 960-SL	C	1	99.2	99.4	99.2	98.6	99.8	98.4
Mobay 960-SL	C	2	98.2	99.6	99.6	98.0	96.6	95.9
		Avg.	98.7	99.5	99.4	98.3	98.1	97.1
No Seal	A	1	100.0	100.0	100.0	98.1	99.4	99.4
No Seal	A	2	100.0	100.0	100.0	98.0	99.3	99.3
		Avg.	100.0	100.0	100.0	98.1	99.3	99.3

Table C-50. Overall longitudinal joint seal effectiveness at Mesa, Arizona test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	33.5	3.8	2.0	0.3
		2	100.0	82.2	62.1	54.2	45.7
		Avg.	100.0	57.8	33.0	28.1	23.0
Crafco SS 444	C	1	100.0	94.4	53.8	25.0	9.0
		2	100.0	99.6	99.3	98.9	97.8
		Avg.	100.0	97.0	76.5	62.0	53.4
Crafco 903-SL	C	1	100.0	99.2	98.2	97.7	98.2
		2	100.0	100.0	99.8	98.9	98.7
		Avg.	100.0	99.6	99.0	98.3	98.5
Dow 888	C	1	100.0	99.3	98.0	98.0	98.0
		2	100.0	100.0	97.6	97.1	97.1
		Avg.	100.0	99.6	97.8	97.5	97.5
Dow 888-SL	C	1	100.0	98.8	98.5	98.5	98.1
		2	100.0	98.5	95.6	94.8	93.9
		Avg.	100.0	98.7	97.0	96.6	96.0
Dow 890-SL	A	1	100.0	99.2	98.4	97.7	96.7
		2	100.0	98.6	93.7	92.3	92.1
		Avg.	100.0	98.9	96.1	95.0	94.4
Dow 890-SL	B	1	100.0	99.8	99.8	99.6	99.2
		2	100.0	99.6	98.7	98.7	98.7
		Avg.	100.0	99.7	99.2	99.2	99.0
Dow 890-SL	C	1	100.0	98.0	97.6	94.4	93.5
		2	100.0	99.8	99.1	99.1	99.0
		Avg.	100.0	98.9	98.4	96.8	96.2
Mobay 960-SL	C	1	100.0	99.2	98.4	98.8	98.4
		2	100.0	99.1	96.6	96.3	95.8
		Avg.	100.0	99.1	97.5	97.6	97.1
No Seal	A	1	100.0	100.0	100.0	99.4	99.4
		2	100.0	100.0	99.5	99.3	99.3
		Avg.	100.0	100.0	99.7	99.3	99.3

Table C-51. Adhesion effectiveness of longitudinal joint seals at Mesa, Arizona test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	44.3	4.6	98.2	100.0
		2	100.0	82.2	62.0	54.2	45.7
		Avg.	100.0	63.3	33.3	76.2	72.8
Crafco SS 444	C	1	100.0	99.6	99.5	96.8	99.1
		2	100.0	100.0	100.0	99.6	99.5
		Avg.	100.0	99.8	99.7	98.2	99.3
Crafco 903-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	99.8	99.8
		Avg.	100.0	100.0	100.0	99.9	99.9
Dow 888	C	1	100.0	100.0	99.3	99.8	98.9
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	99.6	99.9	99.4
Dow 888-SL	C	1	100.0	99.6	99.4	99.4	99.4
		2	100.0	99.1	97.4	97.4	97.0
		Avg.	100.0	99.3	98.4	98.4	98.2
Dow 890-SL	A	1	100.0	99.4	99.0	99.0	98.4
		2	100.0	99.5	98.6	97.6	97.6
		Avg.	100.0	99.4	98.8	98.3	98.0
Dow 890-SL	B	1	100.0	99.8	99.8	99.6	99.6
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	99.9	99.9	99.8	99.8
Dow 890-SL	C	1	100.0	99.6	99.6	98.8	98.4
		2	100.0	99.8	99.3	99.3	99.1
		Avg.	100.0	99.7	99.5	99.1	98.8
Mobay 960-SL	C	1	100.0	99.8	99.0	99.6	99.4
		2	100.0	99.8	99.8	99.8	99.6
		Avg.	100.0	99.8	99.4	99.7	99.5
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 888	C	X1	100.0	100.0	100.0	100.0	100.0
		X2	100.0	100.0	100.0	100.0	99.8
		Avg.	100.0	100.0	100.0	100.0	99.9
Dow 888	C	X1	100.0	100.0	100.0	100.0	100.0
		X2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0

Table C-52. Cohesion effectiveness of longitudinal joint seals at Mesa, Arizona test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	89.7	91.5	4.1	0.5
		2	100.0	99.6	99.6	99.6	99.3
		Avg.	100.0	94.7	95.6	51.9	49.9
Crafco SS 444	C	1	100.0	95.4	59.0	30.7	11.0
		2	100.0	99.6	99.3	99.3	98.2
		Avg.	100.0	97.5	79.2	65.0	54.6
Crafco 903-SL	C	1	100.0	99.8	99.8	98.5	99.1
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	99.9	99.9	99.2	99.5
Dow 888	C	1	100.0	99.3	99.6	98.9	99.8
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	99.6	99.8	99.4	99.9
Dow 888-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	99.6	99.6	99.6
		Avg.	100.0	100.0	99.8	99.8	99.8
Dow 890-SL	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	99.1	98.9	98.9
		Avg.	100.0	100.0	99.5	99.5	99.5
Dow 890-SL	B	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	99.8	100.0	100.0	100.0
		Avg.	100.0	99.9	100.0	100.0	100.0
Dow 890-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Mobay 960-SL	C	1	100.0	99.4	99.4	99.2	99.2
		2	100.0	100.0	100.0	100.0	99.6
		Avg.	100.0	99.7	99.7	99.6	99.4
No Seal	A	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0
Dow 888	C	X1	100.0	100.0	100.0	100.0	100.0
		X2	100.0	100.0	100.0	100.0	99.6
		Avg.	100.0	100.0	100.0	100.0	99.8
Dow 888	C	X1	100.0	100.0	100.0	100.0	100.0
		X2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	100.0	100.0	100.0

Table C-53. Spall effectiveness of longitudinal joint seals at Mesa, Arizona test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	45 months	60 months	72 months	83 months
Crafco RS 221	C	1	100.0	99.6	99.6	99.6	99.6
		2	100.0	99.3	99.1	98.9	98.9
		Avg.	100.0	99.5	99.4	99.3	99.3
Crafco SS 444	C	1	100.0	100.0	99.8	99.6	99.6
		2	100.0	100.0	100.0	100.0	100.0
		Avg.	100.0	100.0	99.9	99.8	99.8
Crafco 903-SL	C	1	100.0	99.4	99.1	99.1	99.1
		2	100.0	100.0	99.8	99.1	98.9
		Avg.	100.0	99.7	99.4	99.1	99.0
Dow 888	C	1	100.0	100.0	99.3	99.3	99.3
		2	100.0	100.0	97.3	96.7	96.7
		Avg.	100.0	100.0	98.3	98.0	98.0
Dow 888-SL	C	1	100.0	99.2	99.0	99.0	98.6
		2	100.0	99.4	98.5	97.8	97.2
		Avg.	100.0	99.3	98.8	98.4	97.9
Dow 890-SL	A	1	100.0	99.8	99.4	98.6	98.3
		2	100.0	99.1	96.0	95.7	95.5
		Avg.	100.0	99.5	97.7	97.1	96.9
Dow 890-SL	B	1	100.0	100.0	100.0	100.0	99.6
		2	100.0	99.8	98.8	98.8	98.8
		Avg.	100.0	99.9	99.4	99.4	99.2
Dow 890-SL	C	1	100.0	98.3	97.9	95.3	94.8
		2	100.0	100.0	99.8	99.8	99.8
		Avg.	100.0	99.1	98.8	97.6	97.3
Mobay 960-SL	C	1	100.0	100.0	100.0	100.0	99.8
		2	100.0	99.3	97.2	96.6	96.6
		Avg.	100.0	99.6	98.6	98.3	98.2
No Seal	A	1	100.0	100.0	100.0	99.4	99.4
		2	100.0	100.0	99.5	99.3	99.3
		Avg.	100.0	100.0	99.7	99.3	99.3
Dow 888	C	X1	100.0	99.6	99.5	99.5	99.5
		X2	100.0	97.3	97.3	96.7	96.7
		Avg.	100.0	98.5	98.4	98.1	98.1
Dow 888	C	X1	100.0	99.6	99.5	99.5	99.5
		X2	100.0	99.8	99.0	99.0	99.0
		Avg.	100.0	99.7	99.2	99.2	99.2

Table C-54. Longitudinal joint seal performance summary at Wells, Nevada test site.

Material	Cnfg.	Rep. No.	Partial-depth adhesion effectiveness, % edge length	Full-depth adhesion effectiveness, % joint length	Full-depth cohesion effectiveness, % joint length	Partial-depth spall effectiveness, % joint length	Full-depth spall effectiveness, % joint length	Overall effectiveness, % joint length
Crafco 902	C	1	94.7	99.2	95.5	91.9	96.8	91.5
Crafco 902	C	2	90.4	98.0	97.3	93.7	91.2	86.4
		Avg.	92.4	98.6	96.4	92.8	93.8	88.8
Crafco 903-SL	C	1	75.8	98.1	97.3	94.3	85.3	80.6
Crafco 903-SL	C	2	89.5	99.8	95.0	91.3	94.5	89.3
		Avg.	83.2	99.0	96.1	92.7	90.3	85.3
Dow 888	C	1	90.9	98.8	91.1	93.1	91.6	81.5
Dow 888	C	2	95.7	99.8	95.7	93.4	98.7	94.2
		Avg.	93.3	99.3	93.4	93.3	95.2	88.0
Dow 888	C	3	98.5	94.8	99.2	100.0	94.3	88.2
Dow 888	C	4	95.6	94.4	97.4	100.0	93.1	84.9
Dow 888-SL	C	1	91.5	86.0	98.6	94.8	89.8	74.4
Dow 888-SL	C	2	96.8	91.2	99.4	93.6	96.6	87.2
		Avg.	94.2	88.7	99.0	94.2	93.2	80.9
Dow 890-SL	C	1	84.4	95.0	100.0	93.1	76.0	71.0
Dow 890-SL	C	2	77.2	88.5	99.8	92.7	95.7	84.0
		Avg.	80.3	91.3	99.9	92.8	87.1	78.3
Mobay 960	C	1	98.3	98.3	86.0	96.7	95.6	79.9
Mobay 960	C	2	96.0	99.6	94.6	93.6	88.3	82.5
		Avg.	97.1	99.0	90.5	95.1	91.8	81.2
Polyethylene	F	1	100.0	100.0	100.0	100.0	79.2	79.2
No Seal	C	1	100.0	100.0	100.0	100.0	100.0	100.0

Table C-55. Overall effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Overall effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	98.3	96.4	92.8	91.0
		2	100.0	97.3	93.7	89.0	85.3
		Avg.	100.0	97.8	95.1	90.9	88.2
Crafco 903-SL	C	1	100.0	96.4	93.9	85.1	80.6
		2	100.0	98.1	94.9	91.8	89.3
		Avg.	100.0	97.2	94.4	88.4	84.9
Dow 888	C	1	100.0	97.4	94.1	86.5	80.7
		2	100.0	98.0	96.3	94.2	93.6
		Avg.	100.0	97.7	95.2	90.3	87.1
Dow 888	C	1	100.0	98.0	95.1	87.2	83.7
		1	100.0	98.5	95.8	88.1	82.9
Dow 888-SL	C	1	100.0	99.1	98.4	86.2	75.8
		2	100.0	99.1	99.1	93.7	86.2
		Avg.	100.0	99.1	98.7	89.9	81.0
Dow 890-SL	C	1	100.0	94.9	92.2	75.6	70.6
		2	100.0	98.2	98.1	93.9	84.6
		Avg.	100.0	96.5	95.2	84.8	77.6
D.S. Brown V-812	D	1	100.0	85.5	43.7	42.5	29.8
Mobay 960	C	1	100.0	96.9	92.2	84.1	79.3
		2	100.0	95.7	92.0	86.1	83.4
		Avg.	100.0	96.3	92.1	85.1	81.3
No Seal	C	1	100.0	100.0	100.0	100.0	100.0
Polyethylene	F	1	100.0	100.0	100.0	87.8	75.7

Table C-56. Adhesion effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Adhesion effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	100.0	100.0	99.5	99.1
		2	100.0	99.8	99.5	99.8	97.2
		Avg.	100.0	99.9	99.8	99.7	98.1
Crafco 903-SL	C	1	100.0	99.8	99.1	99.5	97.7
		2	100.0	99.8	99.8	99.8	99.8
		Avg.	100.0	99.8	99.4	99.7	98.7
Dow 888	C	1	100.0	100.0	99.8	99.5	98.6
		2	100.0	100.0	100.0	99.8	99.8
		Avg.	100.0	100.0	99.9	99.7	99.2
Dow 888	C	1	100.0	99.5	97.9	92.8	92.8
		1	100.0	99.3	99.3	94.9	94.9
Dow 888-SL	C	1	100.0	99.5	98.4	94.9	83.3
		2	100.0	99.3	99.3	94.9	89.1
		Avg.	100.0	99.4	98.8	94.9	86.2
Dow 890-SL	C	1	100.0	99.8	99.8	99.1	94.7
		2	100.0	97.9	97.7	95.6	84.0
		Avg.	100.0	98.8	98.7	97.3	89.4
D.S. Brown V-812	D	1	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	99.5	99.8	99.1	97.9
		2	100.0	99.8	99.8	100.0	99.5
		Avg.	100.0	99.7	99.8	99.5	98.7
No Seal	C	1	100.0	100.0	100.0	100.0	100.0
Polyethylene	F	1	100.0	100.0	100.0	100.0	100.0
	D	2	100.0	100.0	100.0	100.0	100.0

Table C-57. Cohesion effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Cohesion effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	98.1	95.8	95.1	94.4
		2	100.0	98.8	97.5	96.5	96.3
		Avg.	100.0	98.5	96.6	95.8	95.4
Crafco 903-SL	C	1	100.0	100.0	100.0	97.5	96.8
		2	100.0	98.4	94.2	93.3	93.1
		Avg.	100.0	99.2	97.1	95.4	94.9
Dow 888	C	1	100.0	97.9	94.2	90.7	89.4
		2	100.0	97.9	96.8	94.9	94.7
		Avg.	100.0	97.9	95.5	92.8	92.0
Dow 888	C	1	100.0	99.1	99.1	98.8	98.8
		1	100.0	99.3	98.1	97.7	97.7
Dow 888-SL	C	1	100.0	99.8	100.0	98.6	98.4
		2	100.0	99.8	99.8	99.5	99.3
		Avg.	100.0	99.8	99.9	99.1	98.8
Dow 890-SL	C	1	100.0	100.0	100.0	100.0	100.0
		2	100.0	99.8	99.8	99.8	99.8
		Avg.	100.0	99.9	99.9	99.9	99.9
D.S. Brown V-812	D	1	100.0	100.0	100.0	100.0	100.0
Mobay 960	C	1	100.0	97.2	92.4	86.6	83.1
		2	100.0	97.2	93.5	93.5	92.8
		Avg.	100.0	97.2	92.9	90.0	88.0
No Seal	C	1	100.0	100.0	100.0	100.0	100.0
Polyethylene	F	1	100.0	100.0	100.0	100.0	100.0
	D	2	100.0	100.0	100.0	100.0	100.0

Table C-58. Spall effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Spall effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
Crafco 902	C	1	100.0	100.0	100.0	97.0	96.1
		2	100.0	98.1	95.1	90.0	88.0
		Avg.	100.0	99.1	97.6	93.5	92.0
Crafco 903-SL	C	1	100.0	96.1	94.0	85.4	82.6
		2	100.0	99.3	98.8	95.6	92.4
		Avg.	100.0	97.7	96.4	90.5	87.5
Dow 888	C	1	100.0	99.1	99.1	94.4	90.0
		2	100.0	100.0	99.3	98.8	98.4
		Avg.	100.0	99.5	99.2	96.6	94.2
Dow 888	C	1	100.0	99.3	97.5	92.1	92.1
		1	100.0	98.8	95.8	90.3	90.3
Dow 888-SL	C	1	100.0	99.5	99.5	89.4	87.7
		2	100.0	99.8	99.8	98.1	95.8
		Avg.	100.0	99.7	99.7	93.8	91.8
Dow 890-SL	C	1	100.0	94.4	91.7	75.0	74.3
		2	100.0	99.8	99.8	95.8	94.0
		Avg.	100.0	97.1	95.7	85.4	84.1
D.S. Brown V-812	D	1	100.0	99.3	99.1	99.8	99.3
Mobay 960	C	1	100.0	99.8	99.1	95.8	94.7
		2	100.0	96.8	95.4	86.8	84.3
		Avg.	100.0	98.3	97.2	91.3	89.5
No Seal	C	1	100.0	100.0	100.0	100.0	100.0
Polyethylene	F	1	100.0	100.0	100.0	75.7	75.7
	D	2	100.0	100.0	100.0	100.0	100.0

Table C-59. Twist effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Twist effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
D.S. Brown V-812	D	1	100.0	85.2	32.4	33.1	29.6

Table C-60. Compression set effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Compression set effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
D.S. Brown V-812	D	1	100.0	100.0	100.0	100.0	71.5

Table C-61. Gap effectiveness of longitudinal joint seals at Wells, Nevada test site.

Material	Config.	Rep. No.	Gap effectiveness over time, percent joint length				
			0 months	37 months	50 months	62 months	74 months
D.S. Brown V-812	D	1	100.0	100.0	100.0	63.4	99.1