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INNOVATIVE LEAK TEST FOR PAVEMENT JOINT SEALS

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for
Pavement Joint Seals

Progress Report
for
Iowa Highway Research Board
Research Project HR-318

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DISCLAIMER

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ABSTRACT

Premature failure of concrete pavement contraction joint seals is an ongoing and costly problem to the Iowa Department of Transportation. Several joint seal test sections consisting of variations in sawing methods, joint cleaning techniques, sealant installation and sealant types have been established over the past few years. Laboratory analysis and field inspections were done as a part of the tests along with taking core samples for laboratory adhesion pull tests. These test methods often cover specifically small areas and may not expose hidden failures. Some tests are also labor intensive and destructive, especially in the case of coring.

An innovative, nondestructive, broad coverage joint seal tester, which yields quick results, has been designed and developed for evaluation of pavement joint seal performance. The Iowa Vacuum Joint Seal Tester (IA-VAC) applies a low vacuum above a joint seal which has been spray covered with a foaming water solution. Any unsealed area or leak that exists along the joint, will become quickly and clearly visible by the development of bubbles at the leak point. By analysis of the results from the IA-VAC tests, information on the number and types of leaks can be obtained and that information will help identify the source of the problem and direction of efforts toward a solution.

INTRODUCTION

Evaluation of pavement contraction joint seal performance has been underway for many years in search of better seal performance and reduction of joint sealant life cycle costs. A common method of field evaluation is the cold weather visual inspection. As a result of the visual inspection, leaks may sometimes be found by probing, pushing or pulling the seal with an ice pick or knife. A method previously used to test sealant adhesion is based on taking a 10 cm (4 in.) core from over the sealed joint. The two halves of the core, bonded by the sealant, are then slowly pulled apart. This test method was applied to hot poured and cold applied field molded sealants used in previous research projects. Joint sealant testing through the use of cores is very labor intensive, requires a lot of equipment and covers a very small area.

A new method of field evaluation of joint sealants has been developed. The IA-VAC identifies a leaking seal nondestructively within seconds. After spraying the test area with a foaming shampoo-water solution, a low vacuum is applied over the area. Any unsealed area of the joint under the test chamber will immediately generate bubbles identifying the leaking or poor performing sealed area. The IA-VAC test chamber is 122 cm (48 in.) long by 15 cm (6 in.) wide. After analysis and understanding of the number and causes of leaks found, efforts can be more effectively directed toward finding a solution to the problem of joint sealant failures.

OBJECTIVE

The objective of this research is to design and develop a low cost, nondestructive, efficient system for field testing and evaluation of the performance of pavement contraction joint seals.

HISTORY OF FIELD EVALUATION OF PAVEMENT JOINT SEALS

The most common method of determining the performance of pavement contraction joint seals was to make a visual inspection during the coldest season of the year. A visual inspection in a warm season would very normally result in a better apparent sealant performance rating than would be found when the concrete thermal contraction has occurred. A pointed tool, such as an ice pick, was used to push or pull on the seal to determine its bond to the joint faces. This method was applied to the test section in a previous research project (1). A cold season visual inspection rating was given to each joint in the test section annually for 5 years.

Another method of sealant evaluation is by coring and performing adhesion pull tests in the laboratory to determine bonding and elongation properties of sealants from random joints within each test section (2). The testing temperatures used in the test are -29°C (-20°F) and 21°C (70°F). Evaluation by coring is labor intensive and costly and the results apply specifically to only a 10 cm (4 in.) length of a sealed joint (Figure 1). Coring has the additional disadvantage of being destructive.

Results from the old method of testing, using 10 cm (4 in.) core samples, depend largely on individual judgement and opinion. There is a personal bias in selecting the location for the cores as well as judging the failure of the sealant bond during laboratory tests. In addition, some of the personnel making the judgements or visual inspections may change over the years when the data is being collected. This makes the development of a quick, efficient, broad coverage, objective method of field evaluation of joint seals essential. Therefore, out of the need for a better method to evaluate joint seals in the field, IA-VAC was initiated.

DEVELOPMENT OF VACUUM JOINT TESTING

As a result of less than satisfactory performance of many pavement contraction joint seals, especially with the high cost silicone sealants, there was a need to improve evaluations to identify the cause of at least some of the many adhesion failure problems. In most cases, sealant failures were not discovered until after one or more winter seasons after installation.

It was determined that any new test method should be applicable immediately after seal installation and should be nondestructive. With these conditions it would be possible to include in the evaluation the influence of the seal material as well as quality of the joint sawing, sealing procedures and construction skills. It was considered essential to develop a good understanding of the sealed joint condition starting from "day one". The IA-VAC method of testing applies to the performance of the end product. Test results can reflect problems with a seal material system as well as problems resulting from joint sawing, joint cleaning, backer rod, backer rod installation, sealing operations and overall training or experience of construction personnel.

Standard laboratory quality control tests, such as the American Society for Testing and Materials (ASTM) D 3405 for hot pour sealants, are used for preliminary sealant acceptance.

The development of the IA-VAC project was scheduled in 3 phases:

Phase 1 - Development and testing of equipment
Phase 2 - Field testing and gathering of field data
Phase 3 - Analysis of field results and implementation of standard test procedures and specifications.

At the time of writing this report, Phase 1 is completed and Phase 2 is well underway.

PHASE 1 - DEVELOPMENT AND TESTING OF EQUIPMENT

Equipment Design

The first vacuum testing chamber built in this project was a 20 cm (8 in.) x 25 cm (10 in.) x 5 cm (2 in.) metal frame with a plexiglass top and open bottom. The seal used between the bottom of the chamber and the pavement surface was 3M Strip-Calk (Figure 2).

A second generation test chamber built was a 15 cm (6 in.) x 122 cm (48 in.) x 5 cm (2 in.) metal frame with a 6 mm (0.25 in.) clear acrylic top and a flanged open bottom. A Dow Corning 888 self-leveling silicone sealant molded into a triangular cross section with 13 mm (0.5 in.) sides was used for sealing between the bottom of the chamber flange and the pavement surface. After preliminary field testing the seal was changed to a Dow Corning 890 self-leveling silicone molded into a triangular cross section with 19 mm (0.75 in.) sides. The size, shape and quality of that seal was selected to provide an adequate air tight seal for testing on a variety of pavement surface textures including those with transverse grooves 3 mm (0.12 in.) wide x 3 mm (0.12 in.) deep. A vacuum line supply valve and a release valve were installed on one end of the IA-VAC chamber and a vacuum gauge was installed on the other end of the chamber (Figure 3).

A 14 L (0.5 ft^3) vacuum reserve tank was put into the vacuum supply line to help provide sufficient volume for a quick seal onto the pavement. The vacuum line from the reserve tank to the IA-VAC chamber was 6 mm (0.25 in.) x 3 m (10 ft) with quick release couplings. A schematic of equipment used is given in Figure 4.

A 246 watt (0.33 HP) electric Fisher vacuum pump provided a free air delivery of 128 L (4.0 ft^3)/min. A portable generator provided the electric power. The foaming shampoo-water solution was sprayed onto the test area and joint seal from a 11 L (3 gal) hand pressurized sprayer. The sprayer capacity was sufficient for approximately 50 test locations.

PHASE 2 - FIELD TESTING AND GATHERING OF FIELD DATA

Field Testing

Field testing was done from a small van. For a high rate of production testing, three people were required. One person drove the van and recorded joint location and test results. A second person sprayed the test area and joint seal with a foaming water solution. A third person handled the IA-VAC chamber. The vacuum commonly applied for a test was approximately 8 cm (3 in.) of mercury (Hg) or negative 10 kPa (1.5 psi). Test results can usually be determined within seconds after applying the vacuum. Approximately 100 tests can be completed in one hour if no time is used for a detailed analysis. The operation could be done by 2 people at a lower production rate. No personnel were required for traffic control as testing was done on new construction not yet opened to traffic.

In Phase 1 of this project, testing was usually on a random basis, on various roadways, selecting sites of special interest for each joint seal. The main objective was to test the design and performance of the equipment. A typical field testing setup is shown in Figure 5.

The objective of Phase 2 was to develop a large amount of data on various types of sealants and from various sites. Normally, 20 consecutive joints were tested at a particular location, then 20 joints at another location. Identification of the type of leak allows the problem to be better analyzed in search of a solution. Leak test results or failures were recorded by type, such as joint spall, adhesion, cohesion, bubble, etc. Field test results are given in Table 1. It is important to note that all data in Table 1 are taken from new pavement projects and that all testing was done before the project was opened to traffic.

When testing new seal installations, the leaks that are found are normally very short in length, i.e., less than 13 mm (0.5 in.).

Tests done on older sealed joints showed longer failed sections and went as far as total failure with the seal falling to the bottom of the joint. The essential point here is that short sections of unbonded seals, with time, tend to grow to become long sections. IA-VAC is very sensitive to finding the initial short sections of failure in new seal installations. Some predictions of seal longevity may be made based upon the initial test results obtained from a new project.

The results given in Table 1 show a major difference in types of leaks found in hot pour sealant projects compared to a silicone sealant project. In the silicone sealant project, basically all of the leaks were through spalls and all of the spalls were at one end of the project. This clearly points to a sawing related problem at one end of a project that did not exist at the other end.

In the hot pour sealant projects, essentially all of the leaks were from lack of adhesion. Again, the leaks were sometimes found more concentrated in one area of the project. The absence of leaks in other areas of a project, i.e. successful bond, is encouraging. Through further testing and review of project records, the reasons for the difference in number of leaking joints at different locations of the same project may become better understood.

Preformed neoprene joint seals (compression seals) are held in place strictly by their compressive force against the joint face. Theoretically, there is no adhesion as there is with field molded sealants. However, some adhesion may develop from the lubricant adhesive which is used only for the purpose of installing neoprene seals into the joint. It was obvious, from bubbles seen during field tests, that some air passed through the interface of the neoprene seal and the concrete joint face. The amount of air passage appeared to be dependent upon the amount of lubricant adhesive applied. For a properly installed neoprene seal, the amount of water seepage through the seal/concrete interface would be negligible. The anticipated benefit from the high investment in preformed neoprene seals is their long term performance.

Observations

The evaluation of test results based upon the limited data collected so far has led to several interesting observations.

Some of the preliminary observations are:

1. The number of joints with leaks from adhesion failure were sometimes found to be high in one part of a project and low in another part of the same project.

2. Based upon results from random field tests, a preformed neoprene joint seal may show more leaks (air passage) initially than a silicone field molded sealant. The amount of lubricant adhesive used with neoprene seals has a major influence, at least initially, on the amount of air passage.

3. Field test results have shown that the number of leaks due to concrete spalls may be minimal in one area of a project but can change and be a significant number in another area of the same project. The number of spall leaks appears to be affiliated with joint sawing and could be a function of time of sawing, blade type, operator skills, concrete mix, etc.

4. Results from field tests have shown that poor quality control in joint sawing can adversely affect the installation of a backer rod and in turn can result in poor joint seal performance if the backer rod is damaged or sheared.

5. A very low vacuum, such as 8 cm (3 in.) of Hg or negative 10 kPa (1.5 psi) with IA-VAC is sufficient to expose joint leaks. Higher levels of vacuum usually only make those existing leaks pass air at a higher rate.

PHASE 3 - ANALYSIS OF FIELD RESULTS AND IMPLEMENTATION OF STANDARD TEST PROCEDURES AND SPECIFICATIONS

Implementation

Phase 3 of the IA-VAC project is dependent upon evaluations and results determined in Phase 2. Some possibilities of implementation are:

1. Continue to use IA-VAC as an information gathering device for research on joint seal performance.
2. Continue to use IA-VAC as a post construction inspection tool and as a device for identifying problems of poor material or installation practices leading to undesirable seal performance. The observations would be distributed to design and construction departments for their consideration.
3. After establishing a specification for sealant performance, based upon information obtained in Phase 2, IA-VAC might be used as a construction inspection device. It could be used to confirm compliance with a specification limiting the maximum amount of leakage.

Benefits From Research

Since the development of IA-VAC and as additional test data are being accumulated, it is already becoming more evident what some of the underlying reasons are for leakage along pavement contraction joints. These reasons can be uniquely different from project to project. From the preliminary work with IA-VAC, some reasons for leakage along a joint seal were observed which were not generally expected. From six different new projects covering three types of sealing materials the major reasons for leakage were:

A. Preformed Neoprene Seals
   1. Variable amount of lubricant adhesive used
   2. Irregular sawed joint width
B. Self-Leveling Silicone Sealant
   1. Joint spalls made from sawing
C. Hot Poured Rubberized Asphalt Sealant
   1. Poor joint cleaning or no adhesion
   2. Improper installation of backer rod, as a result of bad sawing

IA-VAC can play an important role in predicting the longevity of pavement joint seals. By doing tests on seals on new construction, information on the initial condition will be obtained. With repeated nondestructive research testing performed annually on the same project, the rate and type of joint seal deterioration can be established over time. From the annual data obtained, joint seal longevity can be predicted.

Another benefit from this research is the improvement in quality of worker performance due to the awareness of the testing ability of IA-VAC. Contractors are very interested in IA-VAC test results and are now more concerned about providing quality sealed joints. They are aware that joint seal performance, which includes material and installation quality, can be easily tested by IA-VAC before the project is accepted.

This research project might be considered the first generation of IA-VAC. It is very realistic to envision a second generation in the future, an automated version of IA-VAC mounted across the rear of a van. It could be operated by hydraulic or air cylinders using the vehicle weight in assisting IA-VAC to seal onto the pavement and might cover a 2.4 m (8 ft) test span. The same principle of testing could also apply to certain bridge joint seals. Due to the simplicity of IA-VAC, equipment costs should be quite low.

CONCLUSIONS

IA-VAC offers a very sensitive, quick, simple, nondestructive method for testing leakage in pavement joint seals. It is capable of detecting many leaks that cannot be found by a visual inspection.

The development and use of IA-VAC brought a major increase in awareness of pavement contraction joint seal performance problems. Test results can be routinely obtained along consecutive joints, covering 122 cm (4 ft), during a time period as short as 30 seconds per joint.

The equipment cost of IA-VAC and accessories, excluding vehicle and portable generator, is less than $1,000.

RECOMMENDATIONS

It is recommended to continue IA-VAC testing to develop a sound data base of joint seal performance in Iowa. On specific projects or sites, testing should be repeated each year to determine rate and type of deterioration. Contractors should be informed of testing techniques and results to assist them in their efforts toward improvements in joint seal performance. After completing Phase 2, consideration should be given to using IA-VAC in Phase 3 as an inspection device to assure compliance with a joint seal performance specification.

ACKNOWLEDGEMENTS

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Kathy Davis of the Iowa Department of Transportation for their support in gathering field test data and preparing this report.

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1. Marks, Vernon J., Transverse Joint Sealing With Various Sealants, Final Report, Iowa Highway Research Board HR-203, September 1983.

2. Harris, Gary, Transverse Joint Sealing With Improved Sealers, Final Report, Iowa Highway Research Board HR-276, September 1991.

Table 1

IA–VAC RESULTS FROM FIELD TESTING

Test Location	Date of Test	# Joints Tested	Type of Sealant	Vac. kPa	Type of Leak					Total # Leaks
					Spall	Cohesion	Adhesion	Bubble	* Other	
Audubon Co. F–58 SBL	10–91	35	***** HP	10			39			39
Story Co. US 30 WBL	5–92	42	*** N	10	13		4		10	27
Hamilton Co. I–35 SBL	6–92	101	** S	10	27			1		28
Linn Co. US 151 SBL	7–92	49	**** HP	10	1		26		1	28
Boone Co. S. Linn St. NBL	7–92	40	***** HP	10			21			21
Cass Co. I–80 WBL	10–92	80	****** S	10	12		5		3	20

* Other includes pores, sand, and excessive joint width
** Dow Corning 890 Self Leveling Silicone
*** D. S. Brown 17 mm Preformed Neoprene
**** W. R. Meadows Sealtight Hot Pour #3405
***** Koch Hot Pour #9030
****** Crafco RoadSaver Silicone SL

Note: One test covers 122 cm of a joint
1 cm = 0.39 inch
1 kPa = 0.30 inch of Hg
1 kPa = 0.15 psi

FIGURE CAPTIONS

1. Laboratory Sealant Adhesion Test
2. 1st Generation Vacuum Test Chamber
3. 2nd Generation Vacuum Test Chamber
4. IA-VAC Chamber Schematic
5. Field Testing Equipment
6. IA-VAC Test Results

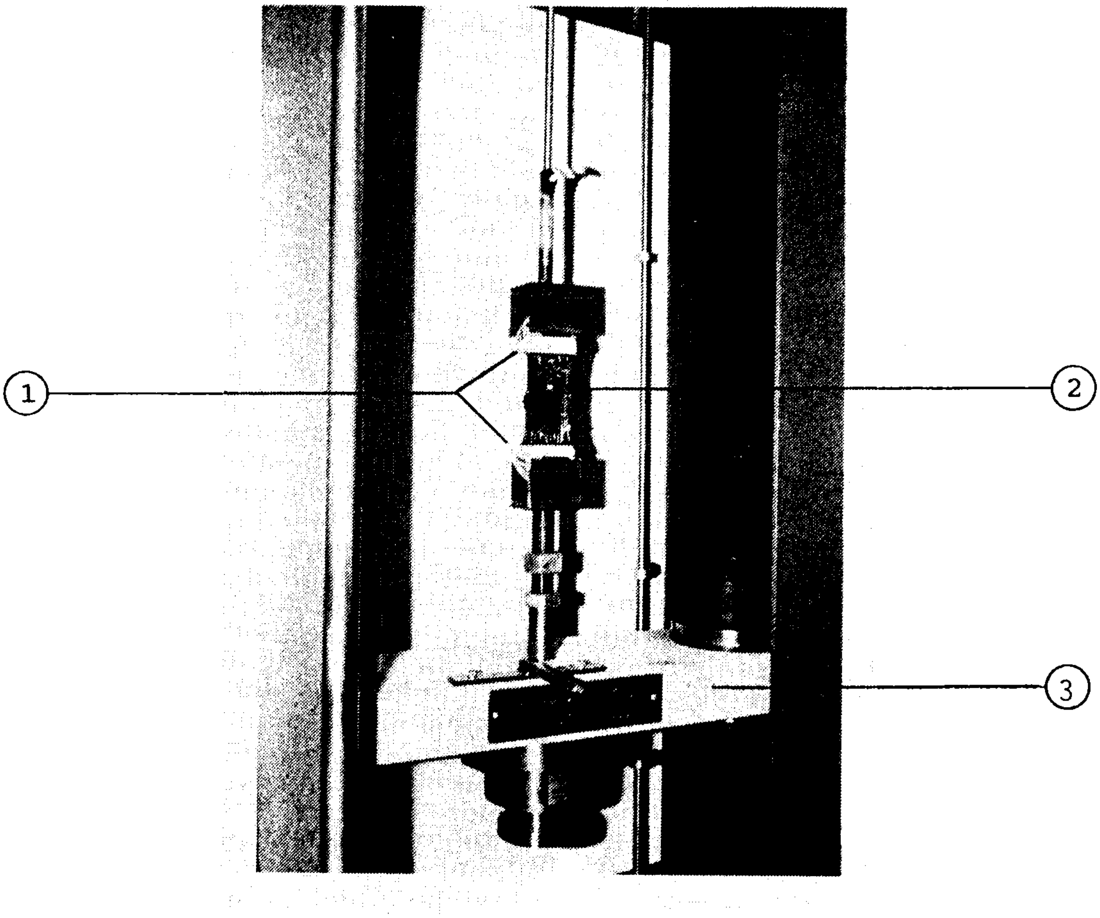


FIGURE 1

LABORATORY SEALANT ADHESION TEST

(1) Core Sections (2) Stretched Sealant

(3) Tinius Olsen Testing Machine

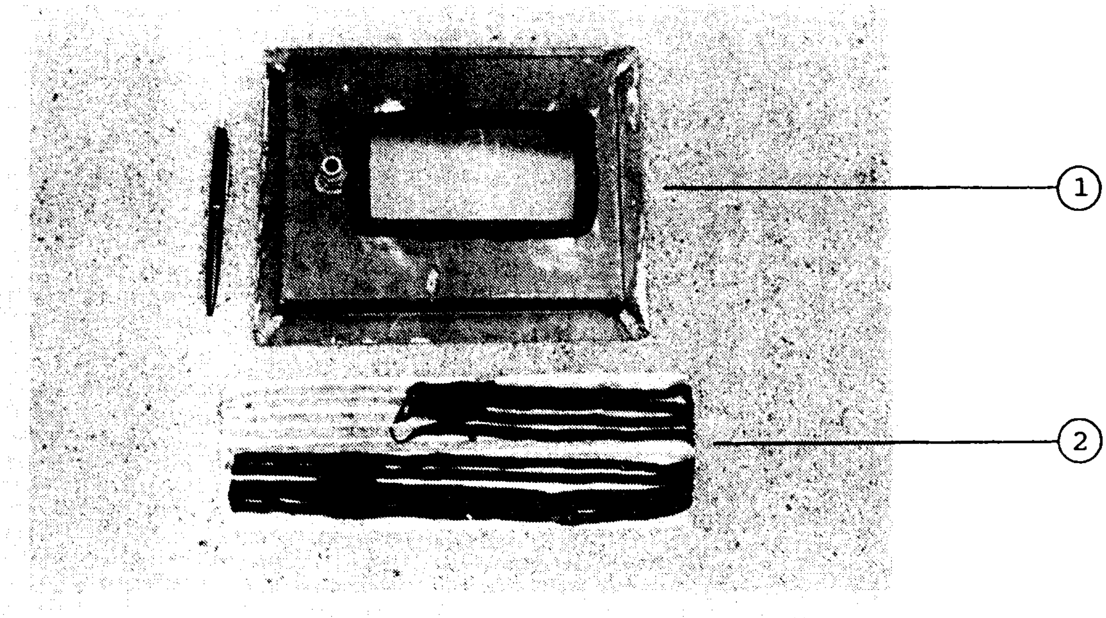


FIGURE 2

1ST GENERATION VACUUM TEST CHAMBER - 20 x 25 x 5 cm

(1) Test Chamber (2) 3M Strip-Calk
(1 cm - 0.39 inch)

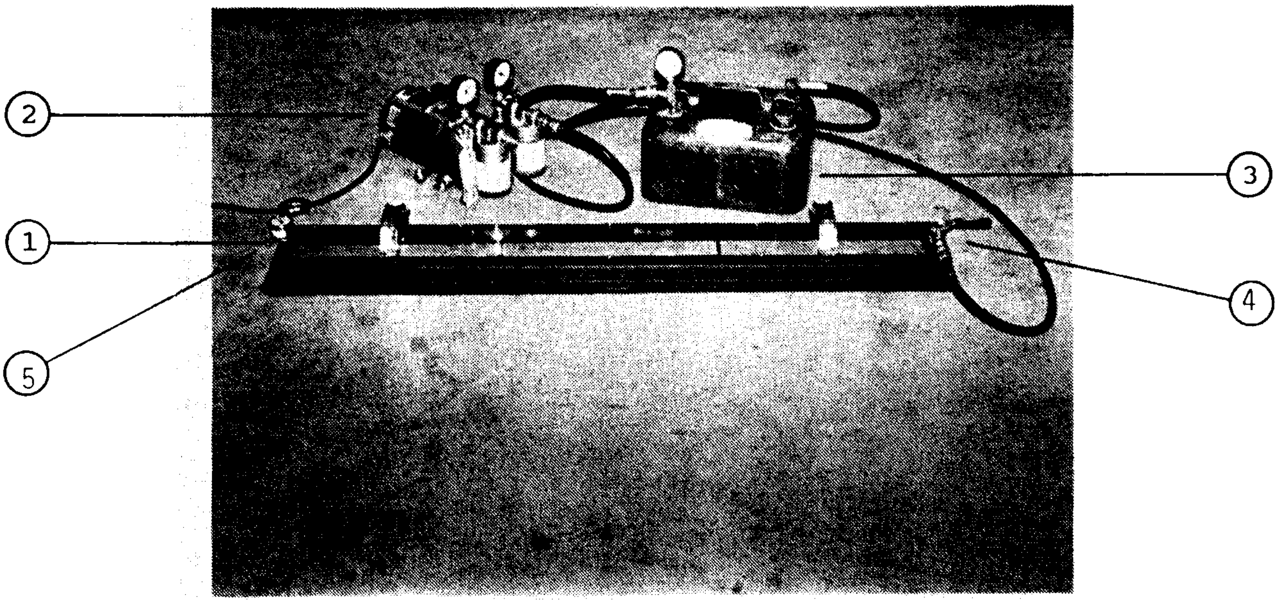


FIGURE 3

2ND GENERATION VACUUM TEST CHAMBER - 15 x 122 x 5 cm

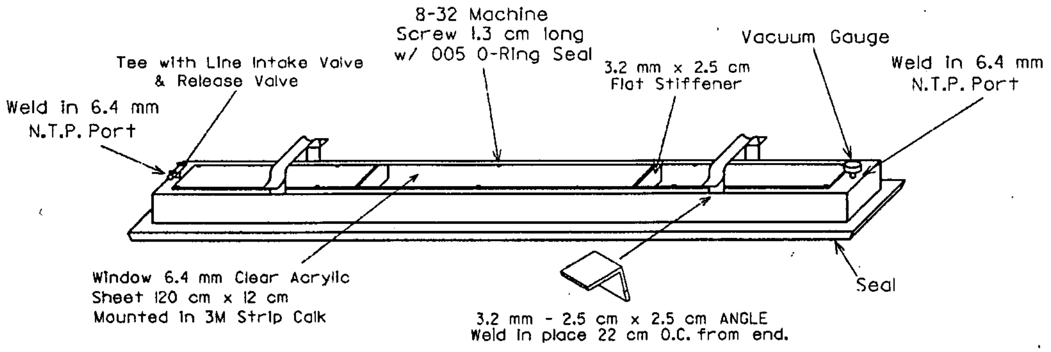
(1) IA-VAC Chamber (2) Vacuum Pump (3) Vacuum Reserve Tank

(4) Vacuum Line Supply Valve and Release Valve (5) Vacuum Gauge

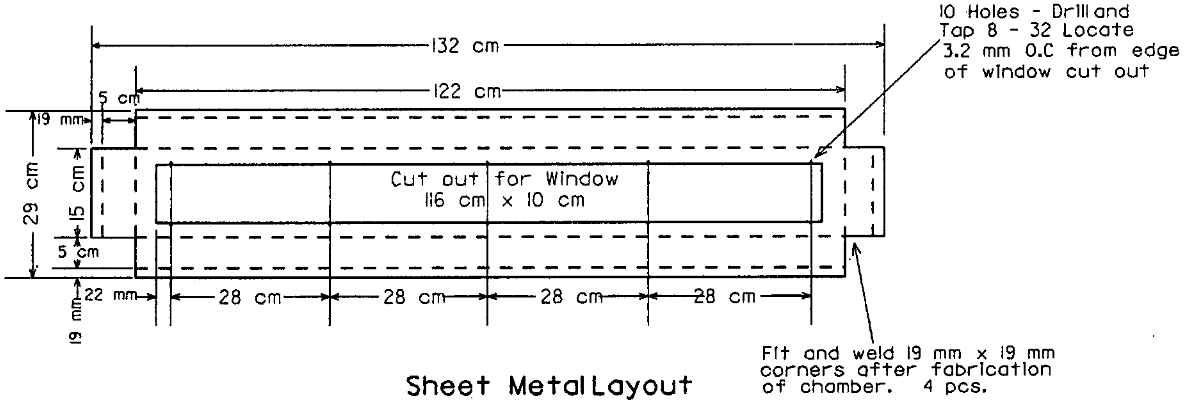
(1 cm = 0.39 inch)

Figure 4

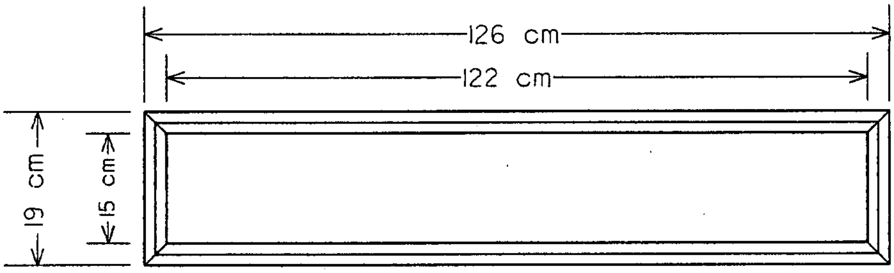
IA-VAC CHAMBER SCHEMATIC



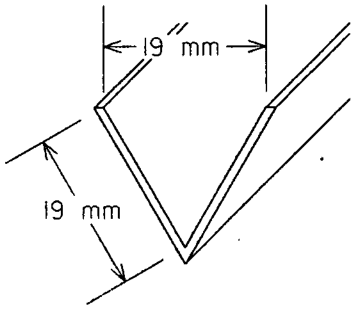
IA-VAC Chamber



Sheet Metal Layout



Top View



Seal Mold

Mold Cross Section

Seal: Dow Corning 890 SL Silicone,
use mold release

Seal Installation: Bond cured seal to rough box
flange surface using additional silicone.

Note: All sheet metal is 16 ga.
Not to Scale

1 cm = 0.39 inch
1 m = 3.28 feet

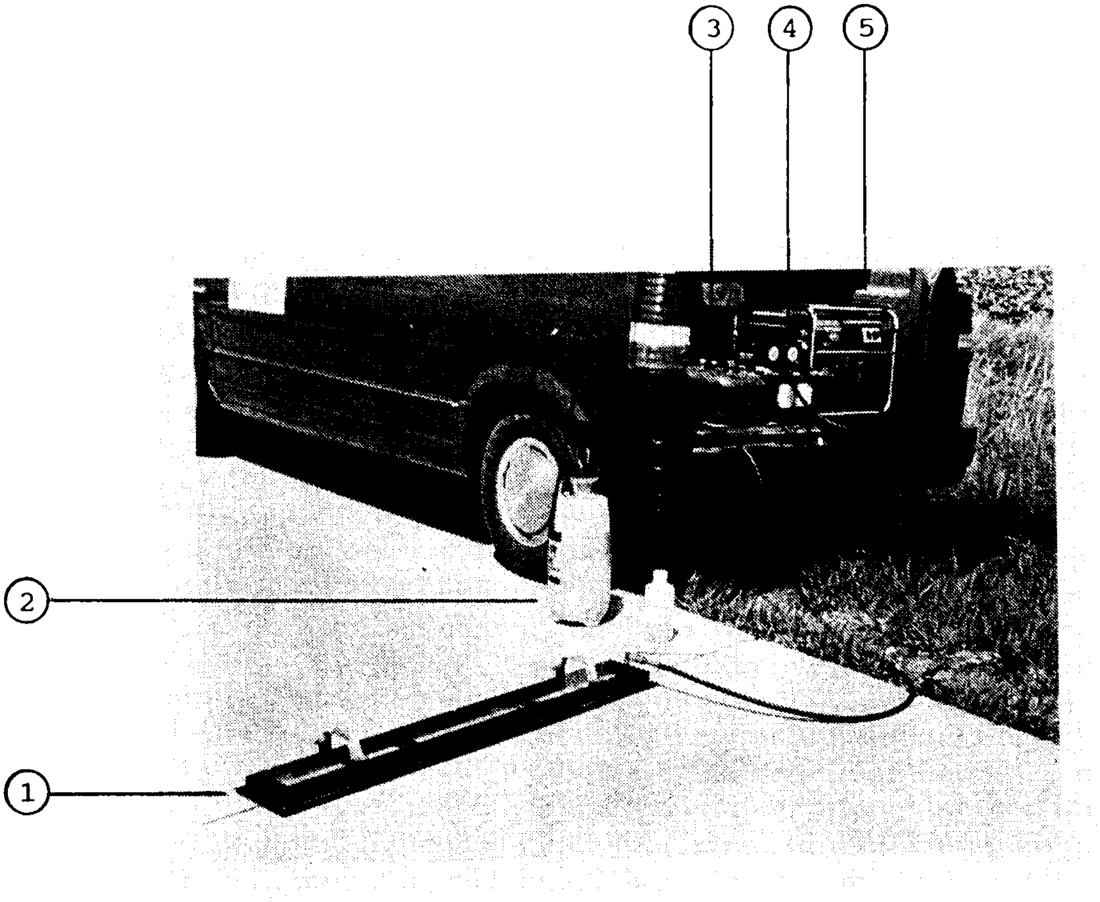


FIGURE 5

FIELD TESTING EQUIPMENT

(1) IA-VAC Chamber (2) Foaming Water Solution

(3) Vacuum Reserve Tank (4) Vacuum Pump

(5) Portable Electric Generator

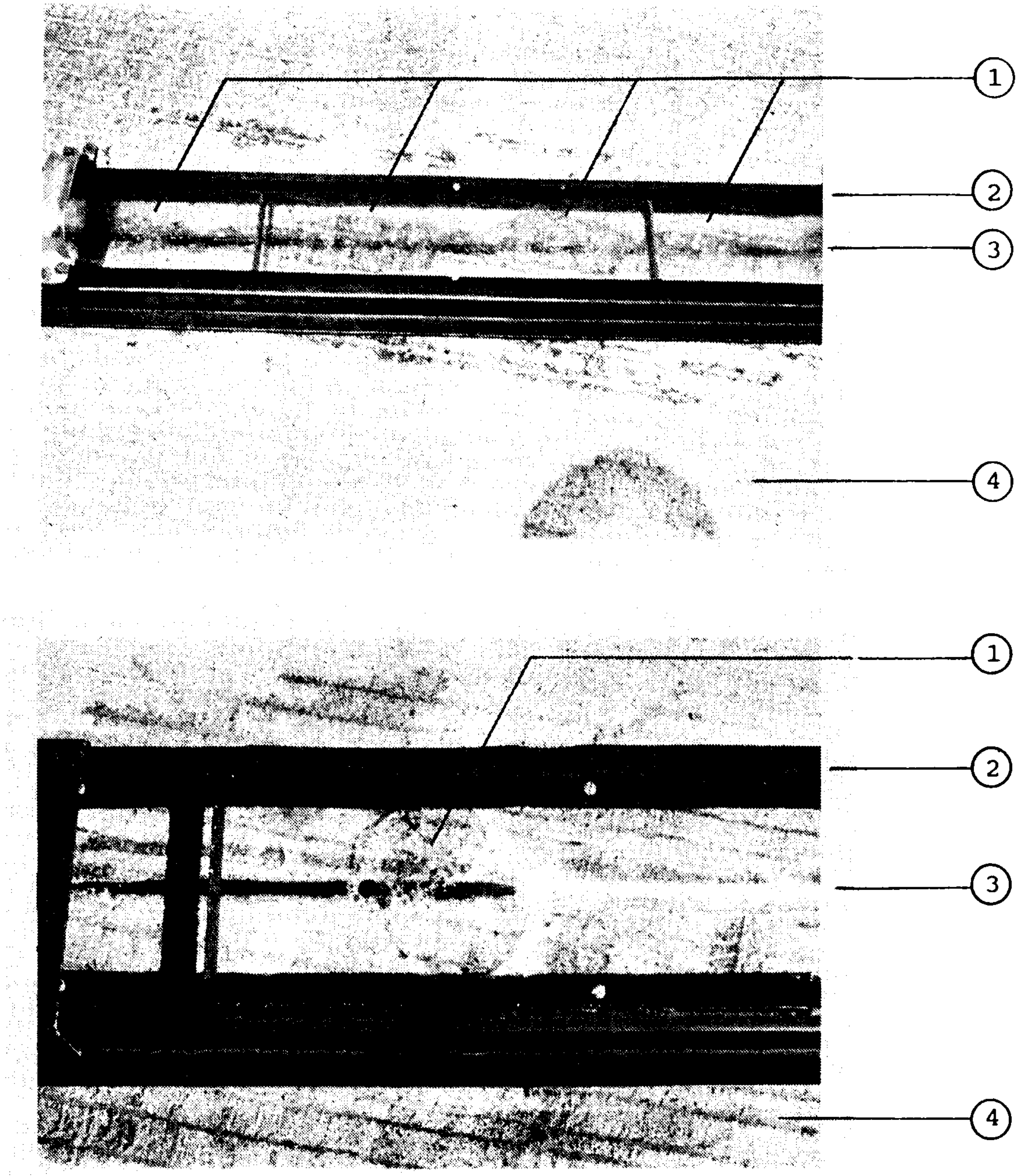


FIGURE 6

IA-VAC TEST RESULTS

(1) Bubbles From Sealant Leaks (2) IA-VAC Chamber

(3) Sealed Joint (4) Grooved Pavement Surface