MICHIGAN DEPARTMENT OF TRANSPORTATION

M•DOT

DETERMINATION OF THE SLIP COEFFICIENT FOR ORGANIC AND INORGANIC PRIMERS IN BOLTED CONNECTIONS

MATERIALS and TECHNOLOGY DIVISION

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ACTION PLAN

1. Materials and Technology Division

   A. Effective January 1, 1992, paint manufacturers submitting inorganic zinc rich primers for acceptance to the Qualified Products List must have certified test results placing their product in the AASHTO Class B (AASHTO Table 10.32.3C "Allowable Loads for Slip Critical Connections"). Notice of the requirement for slip coefficient testing will be provided to all paint manufacturers with the annual request for submittals for the bridge painting program.

   B. Initial notice of the slip coefficient test requirement for the 1992 bridge painting program was sent to paint manufacturers with this year's request for paint submittals. Notice of the slip coefficient test requirement will be included in all requests for submittals to future bridge painting programs.

INTRODUCTION

Slip-critical bolted connections are intended to resist loading primarily through friction between the contact surfaces. When the surfaces slip, the load is then resisted by bearing on the bolts.

Before 1989, Table 1.7.41C2, "Allowable Working Shear Stresses for High Strength Bolts Used for Friction-Type Shear Connectors Based Upon Surface Conditions of Bolted Parts," page 171B of the 1978 Interim to the 1977 AASHTO Standard Specifications for Highway Bridges, governed the design strength of these connections (Table 1). The Michigan Department of Transportation (MDOT) Special Provision for Complete Shop Coating of Structural Steel and Field Repair of Damaged Coatings, Type 4S, specifies the use of an inorganic zinc-rich primer on the faying surfaces (friction surfaces) of these connections. Table 1.7.41C2 loadings allowed by Class F, "Blast-Cleaned, Inorganic Zinc Rich Paint," were used by MDOT bridge design engineers when designing these connections.

Recent research has concluded that the allowable stress should be dependent on the particular primer used. When the 1989 AASHTO Standard Specifications for Highway Bridges was issued it changed the method for determining the slip coefficient (coefficient of friction) of different coating systems used on bolted connection surfaces. AASHTO Table 10.32.3C, "Allowable Load for Slip-Critical Connections" (Table 2), now governs the design of these connections. This specification lists only two design classes for paints and primers, and they are listed by the coefficient of friction rather than by the paint type as they were in the 1978 interim specification. The new specification requires that each coating used in this type of connection be individually evaluated and then placed in either Class A or B.

The 1978 interim specification allowed designers to use 26.5 ksi for inorganic primer-coated surfaces when calculating the allowable slip load per unit of bolt area. MDOT designers have always reduced this to 22 ksi as an additional safety factor. The 1989 specification could reduce this to 15 ksi, if the coating being used falls within Class A. If MDOT were required to use 15 ksi when designing its connections, the size and cost of splice joints and other slip-critical bolted connections would increase dramatically.

Currently, MDOT uses an organic zinc-rich coating as a primer for all non-faying areas of the entire structure. The faying areas of the designed friction connection require an inorganic zinc-rich primer. Masking of the non-faying areas is required before painting the faying area with an inorganic zinc-rich primer. The fabricator must then wait for the coated faying areas to cure before he can mask these areas and coat the rest of the structure. This procedure is time and labor intensive, and thus expensive.

TABLE 1
Allowable Working Shear Stresses for High Strength Bolts Used for Friction-Type Shear Connector. Based Upon Surface Condition of Bolted Parts, in ksi (MPa).

Class of Surface	Surface Condition of Bolted Parts	Standard Holes		Oversize Holes and Short Slotted Holes		Long Slotted Holes	
		M164 (A325)	M253 (A490)	M164 (A325)	M253 (A490)	M164 (A325)	M253 (A490)
A	Clean mill scale	16.0 (110.316)	20.0 (137.895)	13.5 (93.079)	17.0 (117.211)	11.5 (79.289)	14.5 (99.973)
B	Blast-cleaned carbon and low alloy steel	25.0 (172.369)	31.0 (213.737)	21.0 (144.790)	26.5 (182.710)	17.5 (120.658)	21.5 (148.237)
C	Blast-cleaned quenched and tempered steel	17.0 (117.211)	21.0 (144.790)	14.5 (99.973)	18.0 (124.105)	12.0 (82.737)	15.0 (103.421)
D	Hot-dip galvanized and roughened	19.5 (134.447)	24.5 (168.921)	16.5 (113.763)	20.5 (141.342)	13.5 (93.079)	17.0 (117.211)
E	Blast-cleaned, organic zinc rich paint	19.0 (131.000)	23.5 (162.026)	16.0 (110.316)	20.0 (137.895)	13.0 (89.632)	16.0 (110.316)
F	Blast-cleaned, inorganic zinc rich paint	26.5 (182.710)	33.5 (230.974)	22.5 (155.131)	28.5 (196.500)	18.5 (127.552)	23.5 (162.026)
G	Blast-cleaned, metallized with zinc	26.5 (182.710)	33.5 (230.974)	22.5 (155.131)	28.5 (196.500)	18.5 (127.552)	23.5 (162.026)
H	Blast-cleaned, metallized with aluminum	27.0 (186.158)	34.0 (234.421)	23.0 (158.579)	29.0 (199.948)	19.0 (131.000)	24.0 (165.474)
I	Vinyl Wash	15.0 (103.421)	18.5 (127.552)	12.5 (86.184)	16.0 (110.316)	10.5 (72.394)	13.0 (89.632)

Based on AASHTO. . ."Standard Specifications for Highway Bridges." (1978) Table 1.7.41C2.

TABLE 2
Allowable Load for Slip-Critical Connections (Slip Load per Unit of Bolt Area, ksi)

Contact Surface of Bolted Parts	Hole Type and Direction of Load Application							
	Any Direction				Transverse		Parallel	
	Standard		Oversize & Short Slot		Long Slots		Long Slots	
	AASHTO M164 (ASTM A325)	AASHTO M253 (ASTM A490)	AASHTO M164 (ASTM A325)	AASHTO M253 (ASTM A490)	AASHTO M164 (ASTM A325)	AASHTO M253 (ASTM A490)	AASHTO M164 (ASTM A325)	AASHTO M253 (ASTM A490)
Class A (Slip Coefficient 0.33) Clean mill scale and blast-cleaned surfaces with Class A coatings.	15.5	19	13.5	16	11	13.5	9	11.5
Class B (Slip Coefficient 0.50) Blast-cleaned surfaces and blast-cleaned surfaces with Class B coatings.	25	30.5	21.5	26	18	21.5	15.5	18
Class C (Slip Coefficient 0.40) Hot dip Galvanized and rough-ended surfaces	20	24.5	17	20.5	14.5	17	12.5	14.5

Based on AASHTO. . ."Standard Specifications for Highway Bridges." (1989) Table 10.32.3C.

Although it is not commonly believed that organic zinc-rich primers possess a coefficient of friction high enough to place them in Class B, the savings in cost that would be realized by the elimination of the masking and remasking steps, justify this experimental program.

The Design Division requested the Materials and Technology Division to determine the slip coefficient provided by each of the primers listed in MDOT's bridge coating specifications. Since each creep test requires over 1,000 hours (41 to 45 days) for preparation and testing, two primers on MDOT's current approved products list—one organic and one inorganic—were selected. It was decided that independent test data would be required for the remainder.

Objectives

1) To determine the slip coefficient for the two primers most commonly used by the bridge fabrication industry.

2) To determine if the selected organic primer can achieve a coefficient of friction that would place it in Class B, so that the same primer could be used for both friction type and non-friction type faying surfaces.

3) To educate MDOT personnel in this testing procedure so that they can better interpret and critically review the independent laboratory results submitted by paint manufacturers.

PROCEDURE

The two primers selected for evaluation were Amercoat 68A, an organic zinc-rich primer, and Dimetcoat 9, an inorganic zinc-rich primer. Both primers were subjected to all tests described in the "Test Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints," hereafter referred to as the test method. The test method is in the AISC "Specification for Structural Joints Using ASTM A325 or A490 Bolts, Appendix A."

Short-term Static Slip Test

This test was used to determine the slip coefficient (static coefficient of friction) for two individual coatings.

Test Plates - One hundred and five test plates were made from 5/8-in. A36 steel and were saw cut into 4 by 4-in. squares. A 1-in. diameter hole, positioned as shown in Figure 1, was drilled through each plate.

The test plates were degreased with a hydrocarbon blend solvent, then blast cleaned with coarse Staurolite grit until a profile of approximately 2 mils was obtained. The coatings were applied at 3 to 4 mils

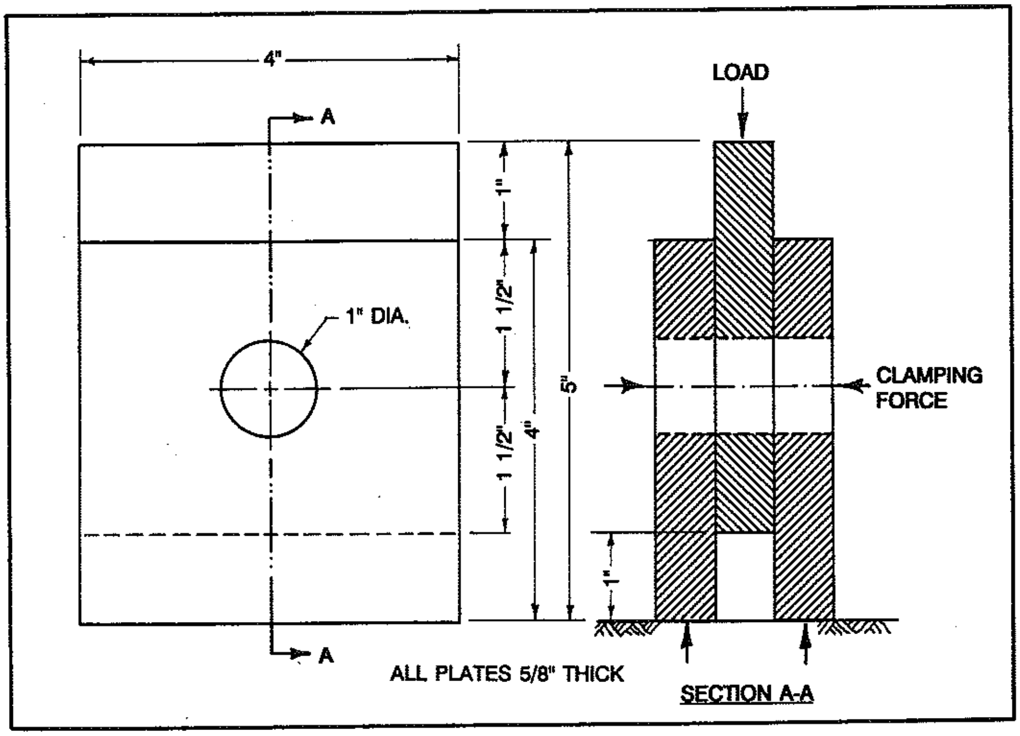

Figure 1. Compression test specimen.

for the inorganic primer, and 6 to 7 mils for the organic primer. Both of these thicknesses were 2 mils heavier than the minimum dry film thickness required by the current Special Provision. Once the paint cured, the dry film thickness was checked using a Positector.

The test specimens were not assembled until just before testing. The date of testing corresponds directly to date of assembly. The dates the specimens were coated, the dry film thicknesses, and the dates of assembly are given in Tables A1 through A6 in the Appendix.

Testing Device - The testing device is shown in Figure 2. A 60-ton hollow core ENERPAC ram was used to supply the required clamping force. The ram was calibrated before testing began. The 7/8-in. diameter rod which runs through the ram and test specimen was made of ASTM A193, grade B7 steel. The center nut was drilled out to remove all of its threads so that it slides over the rod. The vertical load was applied with Structural Research's 200-kip Materials Testing System (MTS).

The vertical displacement of the specimen during loading was initially measured using the linear voltage differential transformer (LVDT) built into the MTS. This did not provide the data needed, so the system shown in Figure 3 was developed. Vertical displacement was measured using two LVDTs fastened to the bottom head of the machine and allowed to rest against the reference bar. Readings of the vertical

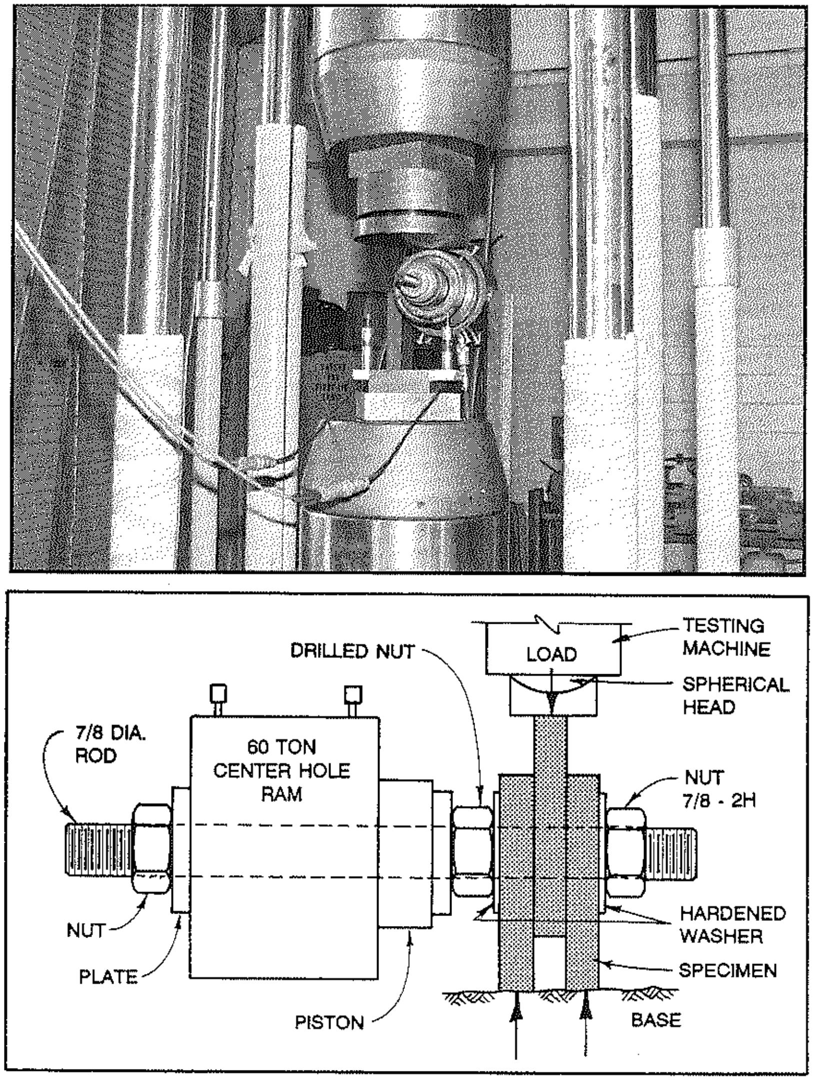

Figure 2. Slip test setup.

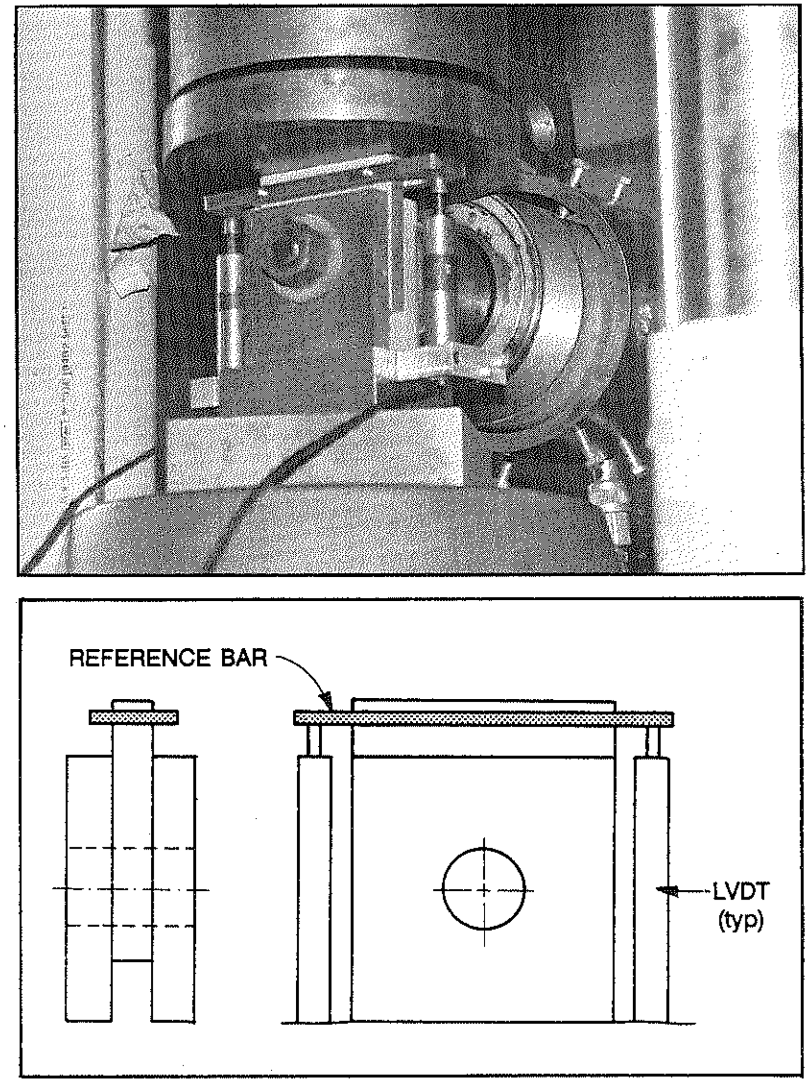

Figure 3. Test specimen with reference bar attached.

displacement from the two LVDTs versus load were recorded on a two-pen X-Y plotter. The average of the two readings was then used.

The test platform was solid and constrained in the test fixture. The top platform was constructed so that it could rotate in two planes to alleviate any small misalignments of the specimens. This ensured that the load was being applied in the vertical direction only.

Specimen Assembly - The test specimen plates were assembled as shown in Figures 2 and 3. The center plate was raised as high as the 7/8-in. diameter rod would allow, so that the maximum slip in the plates could be obtained before the rod came into bearing. Since keeping the plates square during assembly was almost impossible to accomplish while in the testing device, a dummy piece of rod was used. The plates were squared on top and along one side to ensure proper alignment. Once correctly positioned, the plates were temporarily fastened together with a C-clamp.

The reference bar (Fig. 3) was then affixed to the upper plate using allen-head cap screws, and the specimen was placed onto the 7/8-in. diameter rod in the testing device. The hardened washer and nut were then hand-tightened to secure the specimen in place.

Preparations Before Testing Begins - The specimen was aligned in the center of the test platform, and a small clamping force of 1,000 lb was applied with the 60-ton ram. The C-clamp was then removed. A vertical load of 1,000 lb was applied with the MTS to ensure that the specimen was square in the testing device.

An additional clamping force of 48,000 lb was applied to bring the total clamping force to 49,000 lb. The clamping force was monitored during testing and no fluctuations were noted.

Slip Testing - Vertical load was applied at a rate of 20 kips per minute. This is less than the maximum of 25 kips per minute suggested by the test method. The displacement, or slip (recorded by the LVDTs) vs. load was continuously recorded on an X-Y plotter. Increasing loads were applied until a definite slip occurred or a total slip of 0.1 in. was recorded.

Once testing for each specimen was complete, the slip load was calculated from the load vs. slip plot. Figure 4 shows the three types of load versus slip curves that can be obtained, and how the slip load was calculated for each. The organic primer experienced a 'type a' slip with the slip load identified as the highest load recorded. The inorganic primer experienced a 'type c' slip with the slip load identified as the load corresponding to 0.020 in. of slip. The slip loads for both the left and right LVDT were averaged to determined the slip load for each specimen.

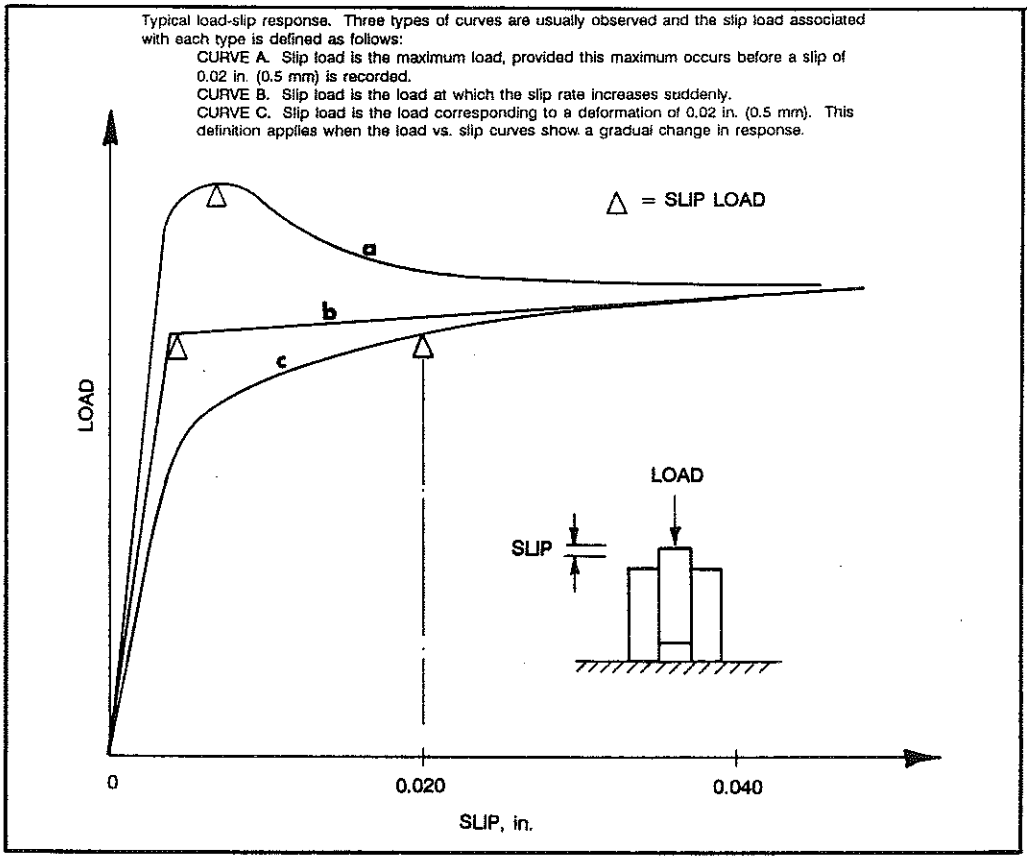

Figure 4. Definition of slip load. Based on AISC. . ."Specification for Structural Joints Using ASTM A325 or A490 Bolts," Appendix A.

The slip coefficient for each group of specimens tested on the same day was calculated using the following formula:

$$K_S = \frac{\text{average slip load}}{\text{2 x clamping force}}$$

Taking the average of all three groups allowed a determination of the initial AASHTO class for each primer.

Long-Term Creep Testing

The purpose of this test is to ensure that the coating will not undergo significant creep deformation during service loading, and also to determine if there will be a loss in clamping force due to the compression or creep of the paint (flow of the zinc particles under load).

Test Plates - Forty-two test plates were made from 5/8-in. A36 steel and were saw cut to the specimen size of 4 by 7 in. Two, 1-in. diameter holes, positioned as shown in Figure 5, were drilled in each plate. Twenty-one plates were used in each specimen string, nine of these plates were coated to make three test specimens.

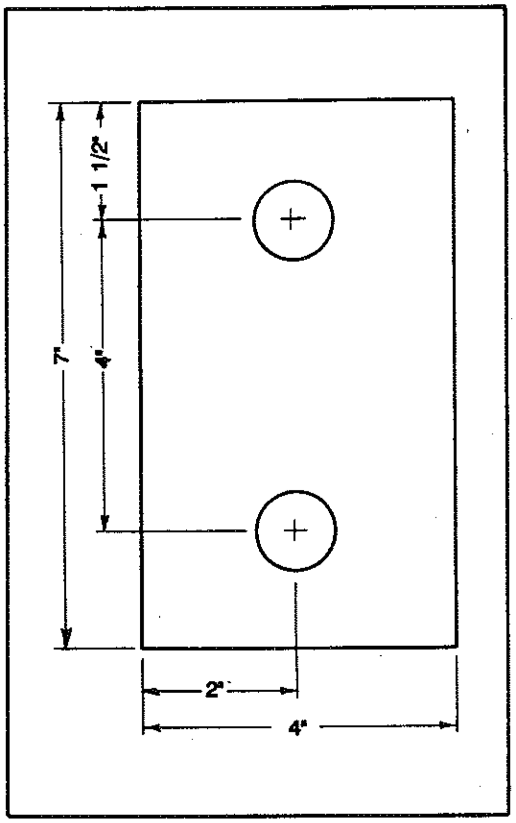

Figure 5. Creep test specimen.

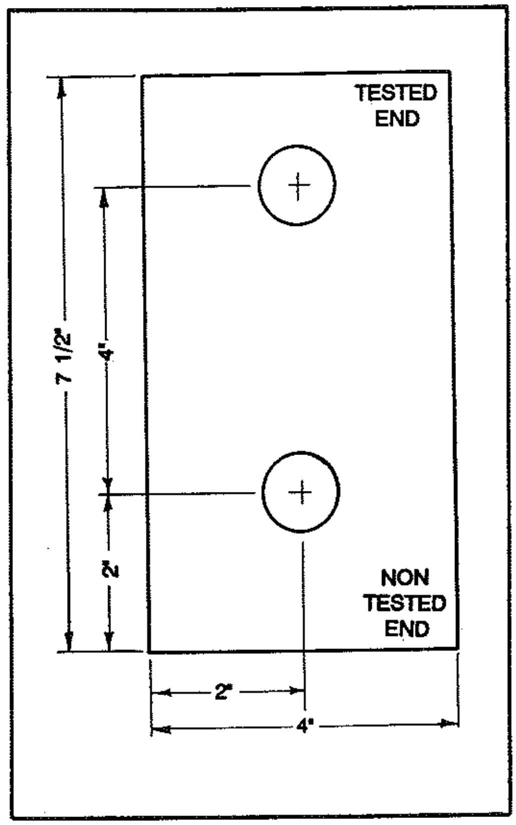

Figure 6. Modified creep test specimen.

At the top and bottom of each test specimen a bolt was placed through the hole and not tightened. When the specimen string was loaded this bolt supported the load in bearing. During the initial test it was discovered that severe deformations were occurring at these bolt holes. It was determined that the specimen was beginning to fail in bearing at these holes. It appears that the test plate was incorrectly designed, and that modification of the test plate was necessary to remedy this problem for the second test.

Twenty-one plates were fabricated for the second test, of which nine were coated to make three test specimens. These plates were 4 by 7-1/2 in. with two 1-in. diameter holes drilled in each plate as shown in Figure 6. The edge distance for the side that was not clamped was increased to 2 in. to decrease the bearing deformation experienced there. This modification would have no effect on the test results.

The test plates were degreased with a hydrocarbon blend solvent, then blast cleaned with coarse Staurolite grit until a profile of approximately 2 mils was obtained. The coatings were applied at 3 to 4 mils for the inorganic primer, and 6 to 7 mils for the organic primer. Both of these thicknesses are 2 mils heavier than the dry film thickness required by the current Special Provision (1 to 2.5 mils for inorganic primers used on faying surfaces and 4 mils for the organic primer). Dry film thicknesses were checked using a Positector.

The test specimens were not assembled until just before testing. The date of testing corresponds directly to date of assembly. These dates, along with the date the specimens were coated, and the dates of assembly, are also recorded in Table A7 in the Appendix.

Testing Device - The testing device is shown in Figure 7.

The required clamping force was attained using 7/8-in. diameter ASTM A490 bolts. A sample of three A490 bolts was subjected to testing in a Skidmore-Wilhelm bolt tensile testing device. The length of each bolt was measured before loading to the nearest one one-thousandth of an inch. The bolts were then loaded to 49,000 lb of tensile load. The lengths of the bolts were remeasured. The average change in length was 0.008 in. Thus if any bolt was elongated by 0.008 in., it was assumed to be exerting a clamping force of 49,000 lb. The vertical load was applied using a lever arm and steel weights (Fig. 7).

To measure the creep of the plates a small angle was placed across the center plate and affixed to the sides of the outside plates (Fig. 8). A smaller angle was then affixed to the center plate. A ball was welded into the center of each angle. Displacement (creep) measurements were taken from the top of one ball to the bottom of the other using calipers.

Specimen Assembly - The length of each test bolt was measured against a blank and permanently marked with the deviation from the test blank. The test specimen plates were assembled as shown in Figure 9. The three plates were laid on their sides with the center plate pressed in as far as a 7/8-in. diameter bolt would permit, to allow the maximum slip in the plates before the rod came into bearing. Once correctly positioned, the plates were fastened together using one of the marked bolts. These bolts were tightened only enough to prevent the plates from falling out of alignment.

Preparations Before Testing Begins - Mathematical calculations were completed to determine what weight need be applied to the end of the cantilever arm to apply the correct tensile loads to the specimen string. In addition, strain gages were mounted to a plate in the specimen string. This plate was calibrated using a Universal testing machine. The plate was then mounted in the test string (Fig. 10).

Creep Testing - Once the string of test specimens was assembled in the test device each bolt was tightened until its elongation equalled 0.008 in. As previously discussed, this elongation corresponded to a total clamping force of 49,000 lb. The loading of the specimen string

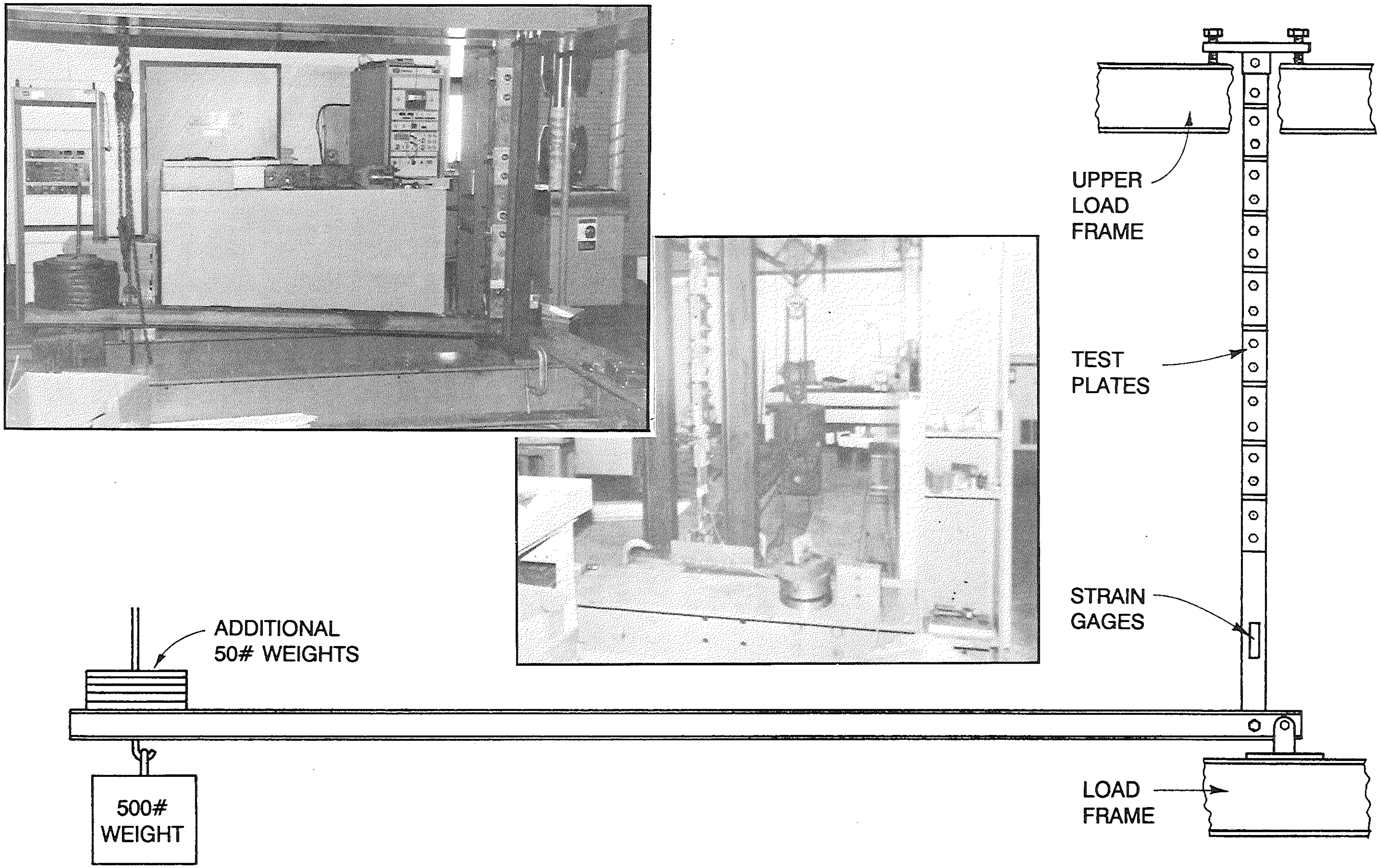

Figure 7. Creep testing device.

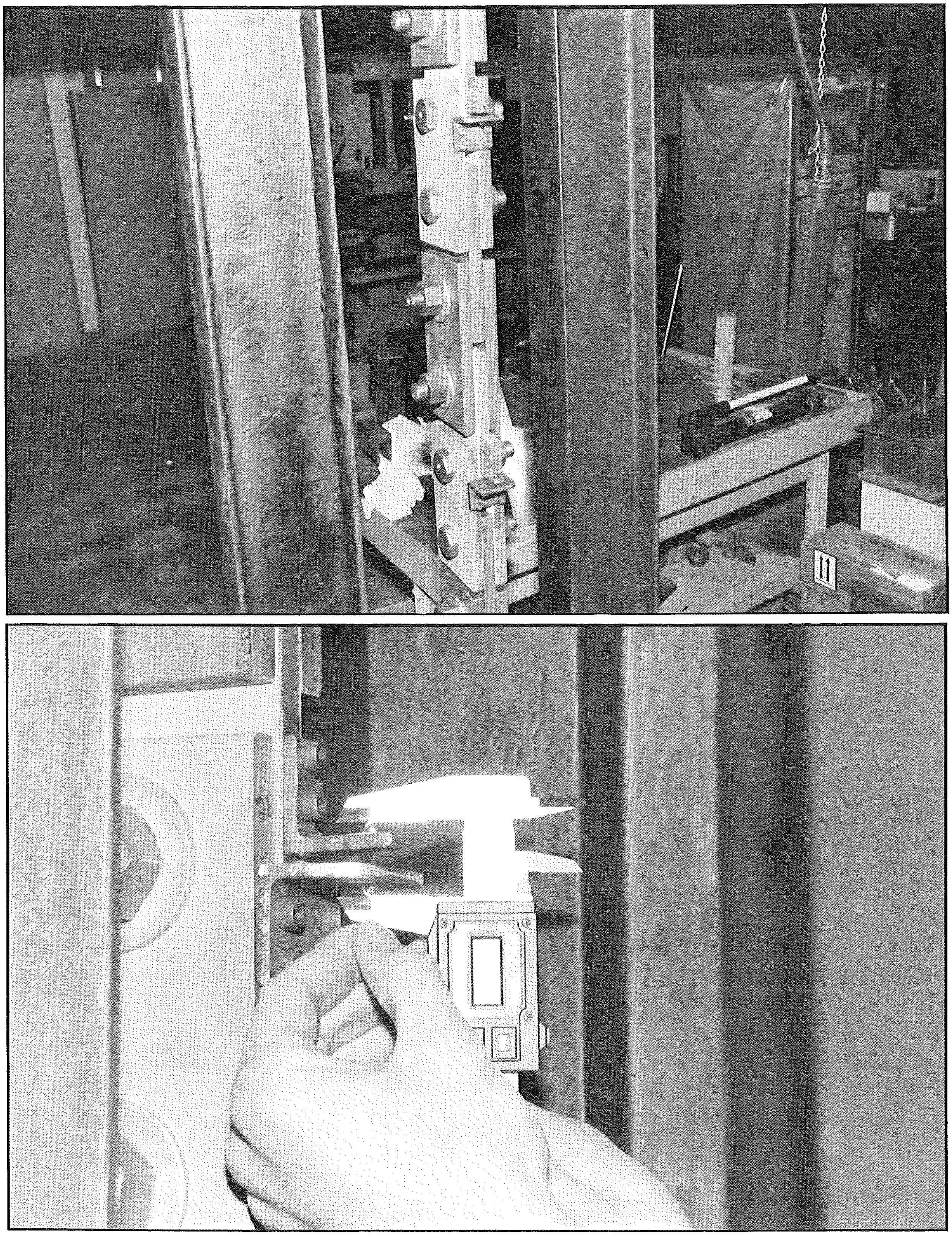

Figure 8. Measurement of Creep.

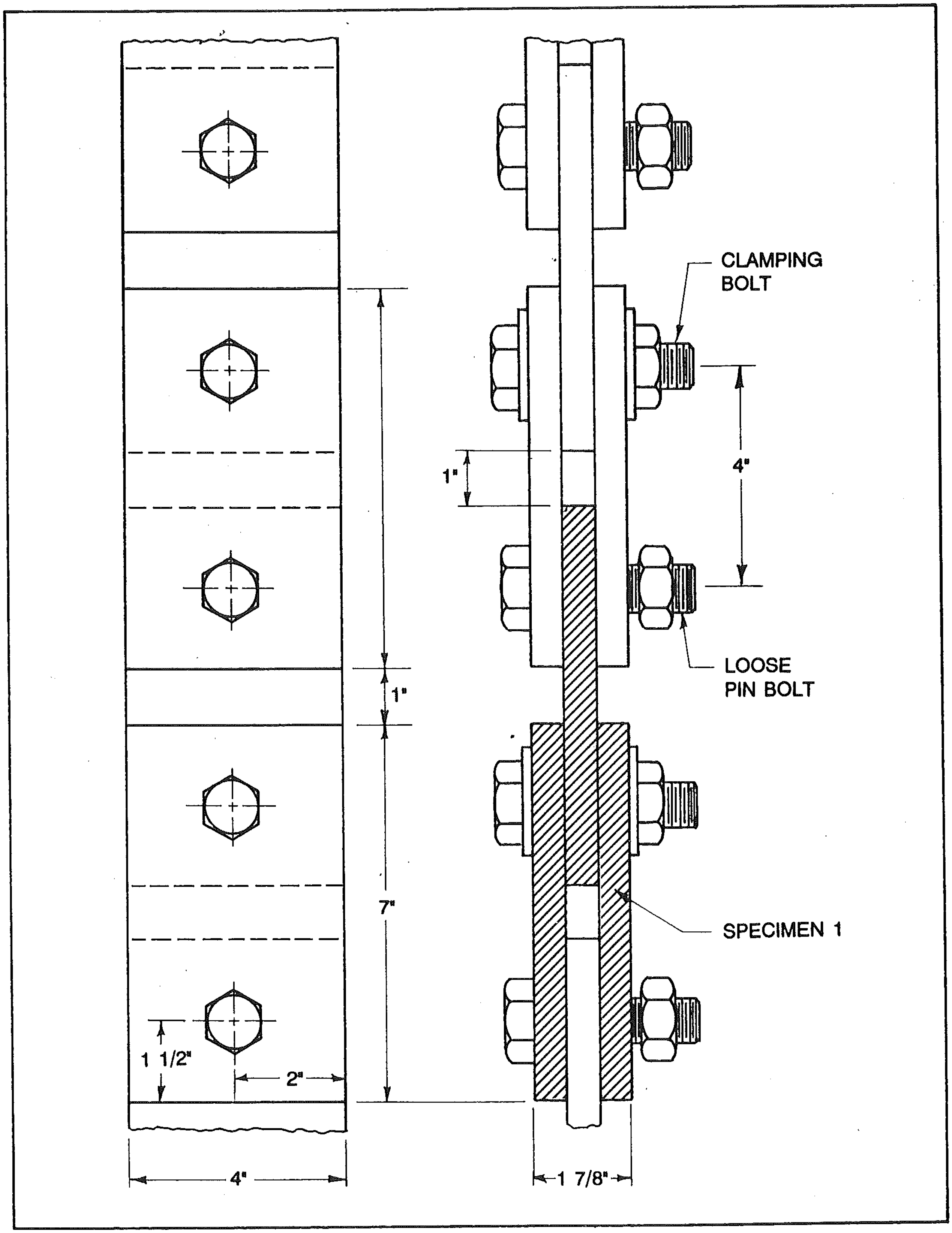

Figure 9. Creep test specimens.

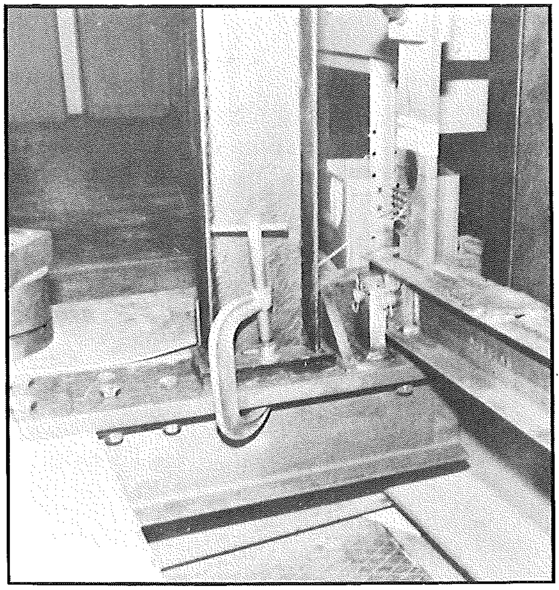

Figure 10. Calibrated strain gages on bottom plate to check applied load.

then began. Vertical load was applied using 50-lb weights which were added to the end of the cantilever arm until the strain gages showed that the correct tensile load in the specimen string had been reached.

The initial load for each primer was determined by the AASHTO class that it was placed in as a result of the slip testing. A tensile loading of 25,250 lb was applied to the organic primer, and 40,900 lb was applied to the inorganic primer. This load was left in place for a minimum of 1,000 hours.

Since most joints will not be loaded at their ultimate capacity all of the time the initial creep loading is lower than that which could be sustained by the joint.

Vertical displacements, the distances from the top of the upper ball to the bottom of the lower ball of each specimen, were recorded for both sides, two to three times per week.

If at the end of the 1,000-hour time period the test specimen had experienced less than 0.005 in. of movement, this portion of the test is considered a success.

The primer under the bolt head and washer may creep due to the clamping force exerted by the bolt, resulting in a lower clamping force. If this occurs it will lower the ultimate load that the joint can sustain. To ensure that a lowering of the ultimate strength of the joint had not occurred, the tensile load was increased to 33,000 lb for the organic and 50,000 lb for the inorganic.

TABLE 3
ORGANIC PRIMER SLIP COEFFICIENT RESULTS
AMERCOAT 68A

GROUP 1
Painted: 7-12-90 Tested: 7-16-90

Specimen No.	Plate No.	Slip Load	Slip Coeff.
1	100 101 102	42,500	0.421
2	103 104 105	36,000	0.357
3	106 107 108	44,000	0.436
4	109 110 111	33,500	0.332
5	112 113 114	31,000	0.307
6	115 116 117	TF[1]	NA[2]
Average		37,400	0.371

GROUP 2
Painted: 7-19-90 Tested: 7-23-90

Specimen No.	Plate No.	Slip Load	Slip Coeff.
19	151 152 153	TF[1]	NA[2]
20	154 155 156	36,000	0.357
21	157 158 159	42,500	0.421
22	160 161 162	33,000	0.327
23	163 164 165	45,000	0.446
24	166 167 168	43,500	0.431
Average		40,000	0.396

GROUP 3
Painted: 8-2-90 Tested: 8-6-90

Specimen No.	Plate No.	Slip Load	Slip Coeff.
25	169 170 171	41,500	0.411
26	172 173 174	41,500	0.411
27	175 176 177	35,500	0.352
28	178 179 180	42,000	0.416
29	181 182 183	43,500	0.431
30	184 185 186	TF[1]	NA[2]
Average		40,800	0.404

[1] Test Failure
[2] Not Available

TABLE 4
INORGANIC PRIMER SLIP COEFFICIENT RESULTS
DIMETCOAT 9

GROUP 1
Painted: 7-12-90 Tested: 7-16-90

Specimen No.	Plate No.	Slip Load	Slip Coeff.
7	118 119 120	57,500	0.570
8	121 122 123	55,000	0.545
9	124 125 126	55,000	0.550
10	127 128 129	59,500	0.590
11	130 131 132	51,000	0.505
12	133 134 135	TF[1]	NA[2]
Average		55,700	0.557

GROUP 2
Painted: 7-19-90 Tested: 7-23-90

Specimen No.	Plate No.	Slip Load	Slip Coeff.
13	133 134 135	47,000	0.466
14	136 137 138	54,000	0.535
15	139 140 141	59,500	0.590
16	142 143 144	TF[1]	NA[2]
17	145 146 147	47,000	0.466
18	148 149 150	61,500	0.609
Average		53,800	0.533

GROUP 3
Painted: 8-2-90 Tested: 8-6-90

Specimen No.	Plate No.	Slip Load	Slip Coeff.
31	187 188 189	57,500	0.570
32	190 191 192	51,500	0.510
33	193 194 195	55,500	0.550
34	196 197 198	56,500	0.560
35	199 200 201	TF[1]	NA[2]
36	202 203 204	58,000	0.575
Average		55,800	0.553

[1] Test Failure
[2] Not Available

Displacement measurements were taken again immediately after loading. If this new displacement was less than 0.015 in. the coating could then be permanently placed in either AASHTO Class A or Class B. If the displacement was larger than 0.015 in. then the paint would need to be tested again at a lower class,if one was available.

RESULTS

Slip Test

The results of the slip tests are recorded in Tables 3 and 4. The resultant means for the three inorganic group tests vary no more than 9 percent, and the resultant means for the three organic group tests vary no more than 5 percent. Both of these numbers are considerably under the maximum 25 percent variation in the mean allowed by the test method.

The mean slip coefficient for all three test groups (each test group included approximately six tests) involving the inorganic primer was determined to be 0.548.

The mean slip coefficient for all three test groups involving the organic primer was determined to be 0.390.

This placed the inorganic primer, Dimetcoat 9, preliminarily in Class B, and the organic primer, Amercoat 68A, preliminarily in Class A.

Discussion

All of the tests conducted and their results are within the parameters set out in the test method. The results indicate that Amercoat 68A can be provisionally placed in Class A pending the results of the creep tests. The results also indicate that Dimetcoat 9 can be provisionally placed in Class B pending the results of the creep tests.

Creep Test

The creep test results are reported in Tables 5 and 6.

For the three organic primer specimens the mean creep at the end of 1,000 hours was 0.002, 0.001, and 0.000 in., respectively. For the three inorganic primer specimens the mean creep at the end of 1,000 hours was 0.000, 0.001, and 0.000 in., respectively. All of these results are well below the allowable maximum of 0.005 specified in the test method.

The slip recorded for each of the three organic specimens after the final load was added was 0.002, 0.001, and 0.000 in., respectively.

TABLE 5
ORGANIC PRIMER CREEP TEST RESULTS
AMERCOAT 68A

	Markings	Readings					Average	Diff.	Specimen Average
DAY 1 INITIAL MEASUREMENTS BEFORE LOADING	1A	0.859							
	2A	0.839							
	3A	0.910							
	1B	0.786							
	2B	0.823							
	3B	0.899							
DAY 1 AUGUST 16 - 3:36 P.M. INITIAL READINGS	1A	0.863	0.862	0.863	0.863		0.863		
	2A	0.839	0.839	0.839	0.839		0.839		
	3A	0.909	0.911	0.910	0.911		0.910		
	1B	0.787	0.786	0.787	0.789		0.787		
	2B	0.823	0.822	0.821	0.822		0.822		
	3B	0.900	0.901	0.899	0.901		0.900		
DAY 40 SEPTEMBER 24 - 10:30 A.M.	1A	0.864						+0.001	
	2A	0.839						+0.000	
	3A	0.911						+0.001	
	1B	0.789						+0.002	
	2B	0.823						+0.001	
	3B	0.901						+0.001	
DAY 43 SEPTEMBER 27 - 11:30 A.M. AFTER FINAL LOADING	1A	0.864	0.863	0.864	0.864	0.863	0.864	0.001	0.002
	2A	0.840	0.839	0.839	0.839	0.839	0.839	0.000	0.001
	3A	0.911	0.910	0.910	0.911	0.910	0.910	0.000	0.000
	1B	0.790	0.790	0.789	0.789	0.787	0.789	0.002	
	2B	0.823	0.824	0.823	0.824	0.822	0.823	0.001	
	3B	0.901	0.900	0.898	0.900	0.900	0.900	0.000	

TABLE 6
INORGANIC PRIMER CREEP TEST RESULTS
DIMETCOAT 9

	Markings	Readings			Average	Diff.	Specimen Average
DAY 1 INITIAL MEASUREMENTS BEFORE LOADING	1A	0.858	0.859	0.859	0.859		
	2A	0.889	0.889	0.890	0.889		
	3A	0.892	0.892	0.892	0.892		
	1B	0.853	0.853	0.853	0.853		
	2B	0.923	0.923	0.923	0.923		
	3B	0.884	0.884	0.885	0.884		
DAY 1 INITIAL READINGS RIGHT AFTER LOADING	1A	0.862	0.861	0.863	0.862		
	2A	0.893	0.892	0.892	0.892		
	3A	0.898	0.897	0.898	0.898		
	1B	0.857	0.857	0.857	0.857		
	2B	0.926	0.927	0.925	0.926		
	3B	0.887	0.888	0.888	0.888		
DAY 1 30 MIN AFTER LOADING	1A	0.862	0.862	0.862	0.862		
	2A	0.892	0.891	0.892	0.892		
	3A	0.898	0.898	0.898	0.898		
	1B	0.857	0.855	0.856	0.856		
	2B	0.925	0.927	0.925	0.926		
	3B	0.887	0.888	0.887	0.887		
DAY 43 NOVEMBER 28 - 8:00 A.M. PRELOADED READINGS	1A	0.862				0.000	
	2A	0.894				0.002	
	3A	0.898				0.000	
	1B	0.857				0.001	
	2B	0.925				-0.001	
	3B	0.887				0.000	
DAY 43 NOVEMBER 28 - 8:00 A.M. AFTER FINAL LOADING	1A	0.861	0.861	0.861	0.861	-0.001	0.000
	2A	0.891	0.893	0.893	0.892	0.000	0.000
	3A	0.928	0.926	0.929	0.928	0.030	0.032
	1B	0.857	0.857	0.857	0.857	0.001	
	2B	0.926	0.926	0.926	0.926	0.000	
	3B	0.923	0.921	0.922	0.922	0.035	

The slip recorded for each of the three inorganic specimens after final loading was 0.000, 0.000, and 0.032 in., respectively.

Discussion

All of the tests conducted are within the parameters set out in the test method. The results of the creep test confirm that Amercoat 68A has a static slip coefficient of 0.390, and can be placed permanently in AASHTO Class A. During the final loading of the creep test, one of the three Dimetcoat 9 specimens experienced a slip of more than 0.015 in. This result fails to confirm that Dimetcoat 9 has a static slip coefficient of 0.548.

There are several possible causes for this failure. One is that the clamping force applied by the bolt caused the paint under the bolt to creep decreasing the tensile force in the bolt, thus lowering the clamping force. This is the type of failure that is most often experienced during the final load portion of the creep test. Although it is possible for only one specimen to fail in this manner, it is more likely that all the specimens would have failed, if this was the problem.

A second possibility is that there was some irregularity in the painted surface that caused the failure. An examination of the failure surface was conducted with no obvious reason for the failure detected.

A final possibility is that the bolt used to clamp this particular specimen was sub-standard. If so the bolt elongation recorded would not have corresponded to the correct clamping force. Unfortunately, we were unable to verify this possibility.

Since there appeared to be no obvious cause for the single failure, the manufacturer, Ameron, was consulted regarding the existence of independent test data pertaining to this product. Ameron responded that several slip coefficient tests had been run on this product with one test group having paint thicknesses in the range required by MDOT's Special Provision. The results of this test placed Dimetcoat 9 in AASHTO Class B. After review of our test results and the independent test results supplied by Ameron, we have concluded that Dimetcoat 9 should be placed permanently in AASHTO Class B.

CONCLUSIONS

1a) Amercoat 68A can be used as an AASHTO Class A coating.

1b) It does not appear that Amercoat 68A, an organic primer, can be used on friction critical faying surfaces.

2) Dimetcoat 9 can be used as an AASHTO Class B coating.

RECOMMENDATIONS

According to AASHTO the Department can only use paints that have been evaluated using the "Test Method to Determine the Slip Coefficient for Coatings Used in Bolted Joints."

We recommend that the individual coating manufacturers be required to submit independent test results that certify the AASHTO class within which their paint system falls. These results should be submitted to the MDOT Research Laboratory's Coatings Group at the same time that the paint is submitted for general acceptance evaluation.

APPENDIX

TABLE A1
PAINT THICKNESS

PRIMER: AMERCOAT 68A
Date Painted: 7-12-90 Date Tested: 7-16-90
MDOT Std + 2 Mils = 6 to 7

Spec. No.	Plate No.	Primer Type	Paint Thickness, mils				
			#1	#2	#3	Plate Avg.	Spec. Avg.
1	100	Organic	6.6	6.7	7.0	6.8	
	101	Organic	6.2	7.0	7.4	6.9	
	102T	Organic	8.1	7.5	6.8	7.5	
	102B	Organic	8.8	7.8	8.3	8.3	7.2
2	103	Organic	8.3	8.4	7.2	8.0	
	104	Organic	6.8	5.8	6.8	6.5	
	105T	Organic	5.7	6.2	6.5	6.1	
	105B	Organic	7.6	7.5	6.6	7.2	7.0
3	106	Organic	7.7	8.5	7.0	7.7	
	107	Organic	7.9	7.6	7.9	7.8	
	108T	Organic	8.6	8.8	8.5	8.6	
	108B	Organic	6.9	7.7	7.9	7.5	7.9
4	109	Organic	7.1	7.4	6.9	7.1	
	110	Organic	6.5	6.2	5.8	6.2	
	111T	Organic	8.0	8.6	8.7	8.4	
	111B	Organic	6.0	5.9	6.0	6.0	6.8
5	112T	Organic	6.3	8.1	6.9	7.1	
	112B	Organic	6.6	6.1	6.6	6.4	
	113	Organic	6.8	6.9	6.3	6.7	
	114	Organic	7.6	7.7	7.3	7.5	7.0
6	115	Organic	6.3	5.9	5.8	6.0	
	116	Organic	6.5	6.2	7.2	6.6	
	117T	Organic	5.9	5.9	5.9	5.9	
	117B	Organic	6.2	7.0	6.4	6.5	6.3

TABLE A2
PAINT THICKNESS

PRIMER: DIMETCOAT 9
Date Painted: 7-12-90 Date Tested: 7-16-90
MDOT Std + 2 Mils = 3 to 4

Spec. No.	Plate No.	Primer Type	Paint Thickness, mils				
			#1	#2	#3	Plate Avg.	Spec. Avg.
7	118T	Inorganic	2.9	3.6	3.5	3.3	
	118B	Inorganic	4.6	3.7	3.8	4.0	
	119	Inorganic	3.9	4.4	4.1	4.1	
	120	Inorganic	4.4	4.3	4.6	4.4	4.1
8	121T	Inorganic	4.0	3.7	3.6	3.8	
	121B	Inorganic	3.7	3.9	3.8	3.8	
	122	Inorganic	3.5	3.4	3.3	3.4	
	123	Inorganic	4.0	3.5	3.3	3.6	3.6
9	124T	Inorganic	3.9	3.9	4.1	4.0	
	124B	Inorganic	4.2	4.1	4.0	4.1	
	125	Inorganic	3.2	3.0	3.4	3.2	
	126	Inorganic	3.7	3.3	3.5	3.5	3.6
10	127	Inorganic	3.5	3.9	3.7	3.7	
	128T	Inorganic	4.2	5.0	4.8	4.7	
	128B	Inorganic	4.2	4.9	4.9	4.7	
	129	Inorganic	3.3	3.3	4.2	3.6	4.0
11	130	Inorganic	3.8	3.5	3.7	3.7	
	131T	Inorganic	3.8	3.8	3.7	3.8	
	131B	Inorganic	4.0	4.1	4.2	4.1	
	132	Inorganic	3.8	4.0	3.5	3.8	3.8

TABLE A3
PAINT THICKNESS

PRIMER: DIMETCOAT 9
Date Painted: 7-19-90 Date Tested: 7-23-90
MDOT Std + 2 Mils = 3 to 4

Spec. No.	Plate No.	Primer Type	Paint Thickness, mils				
			#1	#2	#3	Plate Avg.	Spec. Avg.
	133	Inorganic	3.1	3.1	3.5	3.2	
	134T	Inorganic	2.9	3.0	2.5	2.8	
13	134B	Inorganic	3.6	3.6	3.3	3.5	
	135	Inorganic	4.2	4.2	3.9	4.1	3.5
	136	Inorganic	2.8	3.4	3.4	3.2	
	137T	Inorganic	3.2	3.6	3.3	3.4	
14	137B	Inorganic	4.8	5.1	4.5	4.8	
	138	Inorganic	4.2	3.7	3.5	3.8	3.7
	139	Inorganic	3.3	3.3	3.4	3.3	
	140T	Inorganic	3.8	3.6	3.8	3.7	
15	140B	Inorganic	3.2	4.4	3.8	3.8	
	141	Inorganic	3.6	3.4	3.6	3.5	3.5
	142	Inorganic	3.1	3.0	2.8	3.0	
	143T	Inorganic	2.7	3.1	2.7	2.8	
16	144B	Inorganic	4.1	4.4	4.1	4.2	
	144	Inorganic	3.1	3.5	3.2	3.3	3.3
	145	Inorganic	2.7	3.1	3.1	3.0	
	146T	Inorganic	4.1	4.1	3.8	4.0	
17	147B	Inorganic	3.8	3.6	3.7	3.7	
	147	Inorganic	2.7	3.4	3.8	3.3	3.4
	148	Inorganic	4.0	4.4	4.9	4.4	
	149T	Inorganic	2.2	2.2	2.1	2.2	
18	149B	Inorganic	4.1	3.3	4.0	3.8	
	150	Inorganic	3.3	3.2	3.0	3.2	3.5

TABLE A4
PAINT THICKNESS

PRIMER: AMERCOAT 68A
Date Painted: 7-19-90 Date Tested: 7-23-90
MDOT Std + 2 Mils = 6 to 7

Spec. No.	Plate No.	Primer Type	Paint Thickness, mils				
			#1	#2	#3	Plate Avg.	Spec. Avg.
19	151	Organic	7.8	7.4	8.2	7.8	
	152T	Organic	6.5	5.8	5.7	6.0	
	152B	Organic	6.0	5.5	5.8	5.8	
	153	Organic	7.8	9.1	7.9	8.3	7.3
20	154	Organic	7.1	8.3	8.0	7.8	
	155T	Organic	7.0	7.2	7.2	7.1	
	155B	Organic	7.2	6.8	6.0	6.7	
	156	Organic	7.2	6.9	5.9	6.7	7.1
21	157	Organic	7.2	8.6	9.3	8.4	
	158T	Organic	7.1	6.9	6.0	6.7	
	158B	Organic	7.8	7.3	6.5	7.2	
	159	Organic	7.0	7.1	7.1	7.1	7.5
22	160	Organic	6.4	5.5	6.9	6.3	
	161T	Organic	7.7	9.6	9.5	8.9	
	161B	Organic	3.5	3.5	4.1	3.7	
	162	Organic	4.4	4.6	5.0	4.7	5.8
23	163	Organic	4.2	4.2	5.6	4.7	
	164T	Organic	7.8	6.1	7.3	7.1	
	164B	Organic	7.6	7.0	8.0	7.5	
	165	Organic	6.8	7.0	5.5	6.4	6.1
24	166	Organic	7.4	8.7	7.6	7.9	
	167T	Organic	5.5	6.2	5.2	5.6	
	167B	Organic	7.7	6.3	7.0	7.0	
	168	Organic	6.1	6.0	6.1	6.1	6.8

TABLE A5
PAINT THICKNESS

PRIMER: AMERCOAT 68A
Date Painted: 8-2-90 Date Tested: 8-6-90
MDOT Std + 2 Mils = 6 to 7

Spec. No.	Plate No.	Primer Type	Paint Thickness, mils				
			#1	#2	#3	Plate Avg.	Spec. Avg.
25	169	Organic	9.2	9.4	8.5	9.0	
	170T	Organic	9.6	9.8	9.9	9.8	
	170B	Organic	9.4	9.1	10.0	9.5	
	171	Organic	6.5	8.2	7.8	7.5	8.7
26	172	Organic	7.1	6.8	7.5	7.1	
	173T	Organic	11.7	11.3	10.4	11.1	
	173B	Organic	9.5	10.1	9.8	9.8	
	174	Organic	6.9	7.4	9.4	7.9	8.5
27	175	Organic	7.8	7.4	7.0	7.4	
	176T	Organic	8.1	7.1	7.1	7.4	
	177B	Organic	10.1	11.2	9.5	10.3	
	177	Organic	7.8	8.2	8.8	8.3	8.2
28	178	Organic	8.7	8.3	8.4	8.5	
	179T	Organic	9.2	10.4	9.6	9.7	
	179B	Organic	9.5	9.0	9.0	9.2	
	180	Organic	6.6	6.8	7.2	6.9	8.3
29	181	Organic	7.4	9.0	6.8	7.7	
	182T	Organic	8.9	8.6	8.8	8.8	
	182B	Organic	9.0	9.1	9.7	9.3	
	183	Organic	6.1	6.4	6.3	6.3	7.7
30	184	Organic	6.8	7.5	6.7	7.0	
	185T	Organic	7.7	7.7	8.6	8.0	
	185B	Organic	6.9	8.0	7.9	7.6	
	186	Organic	7.2	6.1	7.3	6.9	7.2

TABLE A6
PAINT THICKNESS

PRIMER: DIMETCOAT 9
Date Painted: 8-2-90 Date Tested: 8-6-90
MDOT Std + 2 Mils = 3 to 4

Spec. No.	Plate No.	Primer Type	Paint Thickness, mils				
			#1	#2	#3	Plate Avg.	Spec. Avg.
31	187	Inorganic	2.1	1.8	2.5	2.1	
	188T	Inorganic	2.7	3.1	2.9	2.9	
	188B	Inorganic	2.5	2.5	2.4	2.5	
	189	Inorganic	2.6	2.4	2.2	2.4	2.4
32	190	Inorganic	3.1	2.9	2.9	3.0	
	191T	Inorganic	2.2	2.6	2.8	2.5	
	191B	Inorganic	2.0	2.2	2.0	2.1	
	192	Inorganic	2.5	2.8	2.2	2.5	2.6
33	193	Inorganic	2.6	2.4	2.4	2.5	
	194T	Inorganic	2.2	2.3	2.4	2.3	
	194B	Inorganic	2.8	2.9	3.4	3.0	
	195	Inorganic	3.0	2.6	3.4	3.0	2.7
34	196	Inorganic	2.1	2.1	2.6	2.3	
	197T	Inorganic	2.1	2.5	2.3	2.3	
	197B	Inorganic	2.2	2.2	1.4	1.9	
	198	Inorganic	3.1	2.8	2.9	2.9	2.4
35	199	Inorganic	2.4	2.6	2.3	2.4	
	200T	Inorganic	3.0	3.3	3.0	3.1	
	200B	Inorganic	2.2	3.2	2.9	2.8	
	201	Inorganic	3.0	2.9	2.3	2.7	2.7
36	202	Inorganic	2.0	1.7	1.8	1.8	
	203T	Inorganic	2.7	2.4	2.1	2.4	
	203B	Inorganic	2.3	2.3	2.3	2.3	
	204	Inorganic	2.1	2.0	2.0	2.0	2.1

TABLE A7
PAINT THICKNESS

Primer	Spec. No.	Plate No.	Primer Type	Paint Thickness, mils #1	#2	#3	#4	#5	Plate Avg.	Spec. Avg.
PRIMER: DIMETCOAT 9 Date Painted: 10-12-90 Date Tested: 10-16-90 MDOT Std + 2 Mils = 3 to 4	1	1A	Inorganic	4.1	3.4	4.0	3.2	3.8	3.7	
		1BA	Inorganic	3.2	3.7	4.1	3.9	3.5	3.7	
		1BC	Inorganic	3.5	3.2	3.5	3.6	3.7	3.5	
		1C	Inorganic	3.7	3.6	3.8	3.3	3.2	3.5	3.6
	2	2A	Inorganic	2.8	2.7	3.2	3.0	2.9	2.9	
		2BA	Inorganic	3.8	4.3	4.4	4.7	3.4	4.1	
		2BC	Inorganic	3.9	4.0	4.1	3.1	3.5	3.7	
		2C	Inorganic	3.1	3.6	3.7	3.8	3.7	3.6	3.5
	3	3A	Inorganic	3.0	3.3	3.3	3.9	4.8	3.7	
		3BA	Inorganic	3.7	3.8	4.4	4.6	3.8	4.1	
		3BC	Inorganic	3.0	2.9	3.0	3.8	3.3	3.2	
		3C	Inorganic	4.7	4.0	4.1	4.3	4.0	4.2	3.8
PRIMER: AMERCOAT 68A Date Painted: 8-13-90 Date Tested: 8-16-90 MDOT Std + 2 Mils = 6 to 7	1	1-1	Organic	7.6	6.2	6.5	7.9	6.4	6.9	
		1-2-1	Organic	8.9	8.3	7.4	7.6	7.2	7.9	
		1-2-3	Organic	8.5	7.4	7.6	7.2	7.1	7.6	
		1-3	Organic	8.2	8.6	8.0	7.7	7.9	8.1	7.6
	2	2-1	Organic	6.0	5.5	6.2	5.4	6.5	5.9	
		2-2-1	Organic	9.6	8.6	8.6	9.1	8.9	9.0	
		2-2-3	Organic	8.6	7.0	6.8	6.6	7.4	7.3	
		2-3	Organic	6.9	7.3	7.3	6.2	8.5	7.2	7.1
	3	3-1	Organic	5.5	6.3	5.1	5.7	5.6	5.6	
		3-2-1	Organic	9.7	10.0	9.7	10.1	9.3	9.8	
		3-2-3	Organic	9.2	7.6	7.6	6.7	7.0	7.6	
		3-3	Organic	7.0	6.9	6.5	6.3	6.3	6.6	7.0