Additional shear wall values for light weight steel framing

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Additional Shear Wall Values for Light Weight Steel Framing

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PREFACE

This report presents the results of 16 monotonic and 28 cyclic tests of flat strap X-braced walls, steel sheathed shear walls, high aspect ratio shear walls and shear walls framed with 54-mil and 43-mil studs.

The findings provided a basis for continued research and development efforts, leading to the establishment of provisions for cold-formed steel-framed diagonal strap braced walls and Type I shear walls.

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ADDITIONAL SHEAR WALL VALUES FOR LIGHT WEIGHT STEEL FRAMING

Report No. LGSRG-1-97

by

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1. INTRODUCTION

1.1 General

AISI sponsored research at Santa Clara University (Serrette, 1996) led to the development of shear values for plywood, oriented strand board (OSB), and gypsum wallboard (GWB) sheathed light weight steel framed wall assemblies. The scope of the 1996 work was, however, limited to plywood, OSB, and GWB on 0.033 in. (20 gauge) framing. To provide a wider range of design options and clarify some of the values from the 1996 test program, a new test program was initiated. The new program included the following wall assemblies: flat strap X-braced walls, steel sheathed walls, high aspect ratio walls, and walls framed with 0.054 in. and 0.043 in. (16 gauge and 18 gauge, respectively) studs. As in the 1996 test program, the new assemblies were tested under static and cyclic loading.

For each wall assembly configuration tested in the current program, the applied load, lateral displacement (at the top plate), slip, uplift, and mode of failure were monitored and recorded. Based on the test results, maximum loads (and corresponding displacements) were interpreted for design.

1.2 Scope

The test program was broken out into five phases based on the desired project goals. The scope of each phase is summarized below:

PHASE 1: Investigate the performance of 4 ft. x 8 ft. 15/32-in. plywood and 7/16-in. OSB wall assemblies framed with 0.033 in. (20 gauge) studs, except for the chords. The chords comprised 0.043 in. (18 gauge) studs. The sheathing was attached to the frame with fasteners at 3 in./12 in. and 2 in./12 in. (perimeter schedule/field schedule).

PHASE 2: Establish the limit on framing members thickness *(up to 0.054 in. (16 gauge))* for sheathing attached with No. 8 screws. At what thickness does the behavior of the shear wall system change?

PHASE 3: Investigate the performance of 0.033-in. (20 gauge) flat strap X-braced walls framed with 0.033 in. (20 gauge) and 0.043 in. (18 gauge) studs.

PHASE 4: Investigate the performance of 0.027 in. and 0.018 in. (22 and 25 gauge) steel sheath shear wall assemblies.

PHASE 5: Investigate the behavior of sheathed high aspect ratio (4:1) walls.

A total of 44 wall assemblies were tested in this program: 28 cyclic tests and 16 static tests. Detailed descriptions of the tests (including nominal dimensions of the framing members and fasteners) are given in Tables 1 and 2.

2. TEST PROGRAM

2.1 Test Setup

The configurations of the 2 ft. x 8 ft. and 4 ft. x 8 ft. frames are illustrated in Figures 1a and 1b, and details of the stud and track sizes, and the framing screws used are given in Tables 1 and 2. Similar setups were used for the cyclic and static tests, as illustrated in Figure 2. Load was applied along the length of the top track via structural channel. Between the load channel and the top track, a full length, 3-1/2-in. wide, 3/4-in. thick aluminum plate was securely installed to permit relative displacement between the frame and attached sheathing.

Overturning resistance and shear transfer at the base of the wall was accomplished with the use of separate anchor systems, as illustrated in Figure 2. Specifically, for overturning, commercial hold-downs rated at 29,000 lb. (ultimate) were used at each end of the wall. Shear transfer was developed with 7/8-in. or 3/4-in. bolts which attached the bottom track (plate) to the floor of the test frame via a full length 3-1/2-in. aluminum plate. In all tests, the assemblies were braced against out-of-plane displacement along the top loading channel.

For each test, the following measurements were monitored and recorded: slip at the bottom of the wall; displacement at the top of the wall; uplift of the chord studs (both ends for the cyclic tests); and total load applied at the top of the wall.

2.2 Test Procedure

Similar to the 1996 test program, the walls were loaded using displacement control. The loading sequences for the static and cyclic tests are described below.

STATIC TEST LOADING SEQUENCE:

The loading procedure for the static test proceeded as follows:

- The top of the wall was displaced at a rate of 0.10 in. per min, up to a deflection of 0.5 in.
- After reaching 0.5 in. of lateral deflection, the load was released and the wall allowed to recover.
- The wall was then reloaded to a top of wall deflection of 1.5 in.
- After reaching 1.5 in. of lateral deflection, the load was released and the wall allowed to recover.
- Finally, the wall was loaded until failure—decreasing capacity with increasing displacement.

Measurements of displacement and load were recorded every 2 seconds using a Helios Plus data acquisition system.

CYCLIC TEST LOADING SEQUENCE:

For the cyclic tests, a sequential phase displacement protocol was used. In the 1996 AISI shear wall test program the loading frequency was 0.67 Hz (or 1.5 seconds per cyclic). In this test program, the cyclic rate of displacement was set at 1.0 Hz. The displacement input history for the cyclic test program is summarized in Figure 3. Measurements of load and displacements were monitored at a rate of 100 samples per second and recorded at a rate of 50 samples per second using a special purposed data acquisition and control system.

2.3 Instrumentation

The instrumentation used in the static and cyclic tests are illustrated in Figure 2. In the static tests, three electronic displacement transducers measured slip, uplift at the bottom of the wall, and lateral deflection at the top of the wall. The total applied load at the top of the wall was measured using a 20 kip electronic load cell. Similar measurements were recorded in the cyclic test, except that uplift was measured on both ends of the wall.

3. TEST RESULTS

The following discussion of the test results is presented in terms of the 5 phases of the project discussed in Section 1.2. In general, there were no unexpected behaviors of the tested wall assemblies. For more specific comparisons, detailed descriptions of the behavior of the wall assemblies are given in Tables 3 and 4.

PHASE 1: *Cyclic Tests*--The back-to-back 0.043 in. studs were sufficient to prevent local buckling in the chords. The assemblies failed as a result of the screw heads pulling through the plywood and OSB sheathing. As a result, the sheathing became unzipped along the bottom and vertical edges at the bottom of the wall assembly.

PHASE 2: *Cyclic Tests*--Installation of the No. 8 sharp point screws in the 0.054 in. (16 gauge) studs was not possible without predrilling. The predrilled hole diameter was 7/64 in. In the tests with the 18 gauge studs, failure generally resulted from a combination of the screw heads pulling through the sheathing and the screws pulling out of the bottom track or along the chords (bottom half of the wall assembly). Failure in the 16 gauge framed assemblies resulted from shearing of the screws and the screw heads pulling through the sheathing.

PHASE 3: *Static Tests*—Failure in the assemblies with the 4-1/2-in. wide strap resulted from local buckling of the compression chord stud. In the tests with the 7-1/2-in. wide straps, failure resulted from local buckling of the top chord track due to out-of-plane track bending. *Cyclic Tests*—For the assemblies with the 4-1/2-in. wide strap, failure was identical to that observed in the static tests (local buckling in the chord studs). In the 7-1/2-in. strap assemblies failure resulted from local buckling in the top track when the track was pulled out of the plane of the wall and local buckling in the chord stud.

PHASE 4: *Static Tests*—All static tests with metal sheathing were on high aspect ratio wall assemblies (2 ft. x 8 ft.). For the 22 gauge sheathing attached with fasteners at 6 in./12 in., there was significant deformation of the sheathing and failure resulted from unzipping of the sheathing due to rupture at the sheathing edges. When the screw schedule was reduced to 4 in./12 in., the sheathing unzipped at the corners as a result of rupture of the sheathing and there was local buckling in the chord studs. *Cyclic Tests*—In all cases, failure involved a combination of the screw fasteners pulling out of the framing, rupture of the edges of the sheathing, and in some cases local buckling of the chord studs.

PHASE 5: *Static Tests*—In the high aspect ratio tests, failure (characterized by chord stud buckling) was most evident in assemblies with 2 in./12 in. screw schedules and it occurred at a top of wall lateral deflection in excess of 2.0 in. In the walls with less tight screw schedules, the plywood and OSB sheathing remained intact during the entire test. *Cyclic Tests*—The same behaviors observed in the static tests were observed here.

The capacities and corresponding displacements of the tested wall assemblies are summarized in Tables 5 through 8. For the cyclic tests, the maximum positive (+ve) and maximum negative (-ve) loads were taken at the peak of the second loop of the last set of stable hysteretic loops. Detailed load-deflection curves for all the tested assemblies are given Appendices A and B.

4. DISCUSSION OF TEST RESULTS

The following discussion is presented in terms of the different phases of the test program which were described in Section 1.2.

PHASE 1: In the 4 ft. x 8 ft. plywood and OSB assemblies tests, the use of back-to-back 0.043 mm (18 gauge) chord studs permitted the assembly to develop the capacity of the sheathing. The plywood walls were found to be stronger and more ductile (larger displacement at maximum load) than the OSB walls.

PHASE 2: No. 8 screws behaved well in 0.043 in. (18 gauge) studs but fractured in shear when 0.054 in. (16 gauge) studs were used. Based on these results, it is recommended that larger diameter screws be used for shear wall applications with 0.054 in. studs.

PHASE 3: Based on the test results, it appears that two important effects the engineer must be concerned with when designing X-braced walls are (1) the actual yield strength of the strap and (2) the eccentricity resulting from straps on one side only. Strap yield strengths in excess of the specified value may result in connection or chord stud failure since both are designed based on the yield strength of the strap. Under high loads, the eccentricity produced by straps on one side only has a tendency to put both the chord stud and track in strong axis bending. These two behaviors "pull" the track out of plane resulting in premature failure of the wall assembly before development of the strap capacity.

PHASE 4: As indicated above, failure of the steel sheathed wall assemblies resulted from a combination of bearing in the sheet steel along the edges and pullout of screws from the studs. No tension field action (formation of a diagonal tension strap) was evident in these tests.

PHASE 5: As stated above, except for the steel sheathed and OSB sheathed (2 in./12 in.) wall assemblies, no strength failure of the 4:1 aspect ratio walls was observed. Retesting of the plywood and OSB 4:1 walls after full application of the test protocol showed that the wall was capable of developing its previous strength, but there was a significant loss of hysteretic energy dissipation. In particular, on the retest the wall had no strength until the induced displacement reached the previous highest displacement.

5. CONCLUSION and RECOMMENDATIONS

5.1 Conclusions

A series of 28 cyclic and 16 static racking tests were performed on sheathed and X-braced light gauge steel framed wall assemblies to investigate the behavior of these systems and the develop strength values for design. The main conclusions of the test program are highlighted below:

- The capacity of plywood and OSB sheathed walls can be developed for 3 in./12 in. and 2 in./12 in. screws schedules provided the chord studs are designed to exceed the shear capacity of the sheathing. Two options for providing adequate chord capacity are (1) using thicker studs or (2) using multiple (built-up chords). The designer must exercise caution with the maximum stud thickness used.

- No. 8 sharp point screws in 15/32-in. plywood and 7/16-in. OSB wall assemblies should be limited to 0.043 in. (18 gauge) framing. There are two drawbacks when No. 8 sharp point screws are used on 0.054 in. (16 gauge) framing: screws do not penetrate steel without predrilling and No. 8 screws fracture in the shear.

- In the design of X-braced walls with bracing on one side only, the designer must check that eccentricity of the shear load at the connection does not induce failure in the chord or top track due to combined bending and axial load. This is particularly important for heavily loaded walls.

- The steel sheathed wall assemblies behaved well. Using thicker steel sheathing provides higher design capacities, but the mode of failure moves from rupture at the edge of the sheathing to screw pullout from the framing.

- High aspect ratio wall are capable of resisting high loads at relatively large displacements, however, after large events, the wall has low to zero initial stiffness.

5.2 Recommendations

Based on the results obtained in this test program, the following recommendations are suggested:

- Designers should consider designing chord studs and tracks for 150% of the yield strength of the X-braced flat strap.

- Screw manufacturers should consider development of 1 in. No. 10 or greater self-drilling screws for application of sheathing on 0.054 in. framing. Cyclic tests should be performed with this application to verify that fracture in the screws is not a governing mode of failure.

- Research on the interpretation of the test data thus far should be initiated to develop a rational procedure for establishing the nominal design load, safety factors (ASD), and resistance factors (LRFD).

6. ACKNOWLEDGMENTS

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7. REFERENCES

Serrette, R. et. al. (1996). Shear Wall Values for Light Weight Steel Framing, Light Gauge Steel Research Group, Report No. LGSRG-3-96, Santa Clara University, Santa Clara, CA, March.

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Table 1. Scope of statically tested wall assemblies

Test no.	Assembly Description	Structural System Attachment	Panel size
AISI-1 AISI-2	*Structural system*: 4-1/2-in. 20 ga. Flat strap X-bracing one side *Framing:* 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets *(see note 5)*	4 ft. x 8 ft.
AISI-3 AISI-4	*Structural system*: 7-1/2-in. 20 ga. Flat strap X-bracing one side *Framing:* 18 ga. 3-1/2 in. studs and 20 ga. 3-1/2-in. tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets *(see note 6)*	*same as above*
AISI-5 AISI-6	*Structural system:* 7/16-in. APA rated OSB sheathing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	2 ft. x 8 ft.
AISI-7 AISI-8	*same as above*	No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	*same as above*
AISI-9 AISI-10	*same as above*	No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	*same as above*
AISI-11 AISI-12	*Structural system:* 25 ga. steel sheathing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	*same as above*
AISI-13 AISI-14	*Structural system:* 22 ga. steel sheathing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	*same as above*
AISI-15 AISI-16	*Structural system:* 25 ga. steel sheathing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	4 ft. x 8 ft.

Notes:

(1) nominal stud geometry: web depth = 3-1/2 in., flange width = 1-1/2 in., lip depth = 1/2 in., thickness = 0.033 in. (20 ga.) or 0.043 in. (18 ga.)
(2) nominal track geometry: web depth = 3-1/2 in., flange width = 1-1/4 in., thickness = 0.033 in. (20 ga.)
(3) nominal material properties: F_y = 33 ksi (ASTM A 653 SQ 33)
(4) framing screws: No. 8-18 x ½ in. self-drilling modified truss head screw
(5) 20 screws used to attach 4-1/2-in. flat strap to gusset plate *(to develop 1.5 times the yield strength)*
(6) 30 screws used to attach 7-1/2-in. flat strap to gusset plate *(to develop 1.5 times the yield strength)*

Table 2. Scope of cyclically tested wall assemblies

Test no.	Assembly Description	Structural System Attachment	Panel size
AISI-A1 AISI-A2	*Structural system*: 15/32-in. APA rated plywood sheathing one side *Framing:* 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center	No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	4 ft. x 8 ft.
AISI-A3 AISI-A4	*same as above*	No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	*same as above*
AISI-A5 AISI-A6	*Structural system*: 7/16-in. APA rated OSB sheathing one side *Framing:* 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center	No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	*same as above*
AISI-A7 AISI-A8	*same as above*	No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	*same as above*
AISI-B1 AISI-B2	*Structural system*: 15/32-in. APA rated plywood sheathing one side *Framing:* 18 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center	No. 8-18 x 1 in. sharp point flat head screw at **6 in./12 in.**	*same as above*
AISI-B3 AISI-B4	*Structural system*: 15/32-in. APA rated plywood sheathing one side *Framing:* 16 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center	No. 8-18 x 1 in. sharp point screws at **6 in./12 in.**	*same as above*
AISI-C1 AISI-C2	*Structural system:* 4-1/2 in. 20 ga. flat strap X-bracing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws (see note 5)	*same as above*
AISI-C3 AISI-C4	*Structural system:* 7-1/2 in. 20 ga. flat strap X-bracing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center 18	No. 8-18 x ½ in. self-drilling modified truss head screws (see note 6)	*same as above*
AISI-D1 AISI-D2	*Structural System:* 25 ga. steel sheathing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws at **6 in./12 in.**	*same as above*

Notes:

(1) nominal stud geometry: web depth = 3-1/2 in., flange width = 1-1/2 in., lip depth = 1/2 in., thickness = 0.033 in. (20 ga.), 0.043 in. (18 ga.), or 0.054 (16 ga.)
(2) nominal track geometry: web depth = 3-1/2 in., flange width = 1-1/4 in., thickness = 0.033 in. (20 ga.)
(3) nominal material properties: F_y = 33 ksi (ASTM A 653 SQ 33)
(4) framing screws: No. 8-18 x ½ in. self-drilling modified truss head screw
(5) 20 screws used to attach 4-1/2-in. flat strap to gusset plate *(to develop 1.5 times the yield strength)*
(6) 30 screws used to attach 7-1/2-in. flat strap to gusset plate *(to develop 1.5 times the yield strength)*

Table 2. Continued

Test no.	Assembly Description	Structural System Attachment	Panel size
AISI-E1 AISI-E2	*Structural system*: 7/16-in. APA rated OSB sheathing one side *Framing:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center	No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	2 ft. x 8 ft.
AISI-E3 AISI-E4	*same as above*	No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	*same as above*
AISI-E5 AISI-E6	*same as above*	No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	*same as above*
AISI-F1 AISI-F2	*Structural system*: 22 ga. steel sheathing one side *Framing:* 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center	No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	*same as above*
AISI-F3 AISI-F4	*same as above*	No. 8-18 x 1/2 in. self-drilling modified truss head screws at **2 in./12 in.**	*same as above*

Notes:

(1) nominal stud geometry: web depth = 3-1/2 in., flange width = 1-1/2 in., lip depth = 1/2 in., thickness = 0.033 in. (20 ga.), 0.043 in. (18 ga.), or 0.054 (16 ga.)
(2) nominal track geometry: web depth = 3-1/2 in., flange width = 1-1/4 in., thickness = 0.033 in. (20 ga.)
(3) nominal material properties: F_y = 33 ksi (ASTM A 653 SQ 33)
(4) framing screws: No. 8-18 x ½ in. self-drilling modified truss head screw

Table 3. Behavior of statically loaded wall assemblies

Test no.	Assembly description	Behavior of wall assembly
AISI-1 AISI-2	***Structural system***: 4-1/2-in. 20 ga. Flat strap X-bracing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets	■ Buckling in compression chord at the lowest knockout. ■ West side back to back studs failed at lowest electrical hole.
AISI-3 AISI-4	***Structural system***: 7-1/2-in. 20 ga. Flat strap X-bracing one side ***Framing***: 18 ga. 3-1/2 in. studs and 20 ga. 3-1/2-in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets	■ Bending in the top track at the tension strap; Track pulled out of the plane of the wall. ■ Buckling of the top track at the tension strap; Track buckled out of the plane of the wall.
AISI-5 AISI-6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	■ No failure. The test was ended as a result of large lateral deflection of the wall (lateral/top DCDT and ram reached maximum deflection). ■ No failure. When lateral displacement DCDT reached max. deflection it was removed. Loading was continued until ram reached max. extension of 4 in.
AISI-7 AISI-8	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	■ Buckling in the compression chord stud just above the track. ■ Buckling in the compression chord stud just above the track.
AISI-9 AISI-10	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	■ Distortional buckling in the compression chord flanges (at the holdown). ■ Distortional buckling in the compression chord flanges (at the holdown).
AISI-11 AISI-12	***Structural system***: 25 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	■ Significant deformation in the sheathing. ■ Significant deformation in the sheathing.
AISI-13 AISI-14	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	■ Sheathing unzipped along the top unloaded corner and buckling in the chord (~ 2/3 up the chord height). ■ Sheathing unzips at the bottom corner on the ram side.
AISI-15 AISI-16	***Structural system***: 25 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	■ Steel sheathing pulls off the frame. Twisting and buckling in chord. ■ Steel sheathing pulls off the frame. Twisting and buckling in chord.

Table 4. Behavior of cyclically loaded wall assemblies

Test no.	Assembly description	Behavior of wall assembly
AISI-A1 AISI-A2	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	■ Screws pull through plywood sheathing at the bottom corners. ■ Screws pull through plywood sheathing along bottom edge and bottom corners.
AISI-A3 AISI-A4	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	■ Screws pull through plywood sheathing at bottom corner on ram side; Buckling of bottom track after screws pulls through plywood; Buckling in chord stud (open ram side) approx. 2 ft. above bottom track; Edge of plywood sheathing broken at the bottom edge on the non-ram side; Holdown nut spins up/down at the non-ram side during the test. ■ Screws pull through plywood sheathing at the bottom corners; Buckling in bottom track at the shear anchor on the ram side; Fracture of the bottom track at the shear anchor on the non-ram side.
AISI-A5 AISI-A6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	■ Screws break vertical edges of OSB sheathing along 1/3 wall height (from base); Screws pull through OSB sheathing along the bottom edge; One screw at the bottom corner (ram side) was shear (at sheathing-metal interface). ■ SAME BEHAVIOR AS TEST A5
AISI-A7 AISI-A8	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	■ Screws pull through OSB sheathing along bottom edge and along two sides (approx. 1/3 wall height from bottom); Local buckling in the lip of all studs (on open side), except exterior stud on chords. ■ (Fabrication error resulted in pre-mature failure); Otherwise, screws pulled through plywood along the top edge and vertical edges 1/4 wall height from top.
AISI-B1 AISI-B2	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screw at **6 in./12 in.**	■ Screw pulls through panel along vertical edges (bottom half); Screw pulled out of track at bottom corner; Screw shear along the bottom track. ■ Along the bottom track and the vertical (bottom half)- - screws pulled out of stud and track - screws pulled through panel - screw breaks edge of panel (on verticals)
AISI-B3 AISI-B4	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 16 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point screws at **6 in./12 in.**	■ Screw shear along the entire vertical edge (load side); Screw begins to pull out of the bottom track--bottom corner (non-loaded side); Screw pulls through panel at top and bottom track (loaded side). ■ Screws pull through panel along vertical edge and bottom track (loaded edge) -- bottom half; Some screw shear observed; Screws

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		break edge of the panel (non-loaded edge)
AISI-C1 AISI-C2	***Structural system**:* 4-1/2 in. 20 ga. flat strap X-bracing one side ***Framing**:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment**:* No. 8-18 x ½ in. self-drilling modified truss head screws (see note 5)	■ Buckling in both chord studs (at web knockouts) ■ Buckling in both chord studs (at web knockouts)
AISI-C3 AISI-C4	***Structural system**:* 7-1/2 in. 20 ga. flat strap X-bracing one side ***Framing**:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment**:* No. 8-18 x ½ in. self-drilling modified truss head screws (see note 6)	■ Top and bottom track pulled out of the plane of the wall (non-loaded end); Buckling in the chord stud at the loaded end. ■ Top and bottom track pulled out of the plane of the wall (non-loaded end); Buckling in the chord stud observed to occur after bending in top and bottom track.
AISI-D1 AISI-D2	***Structural System**:* 25 ga. steel sheathing one side ***Framing**:* 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment**:* No. 8-18 x ½ in. self-drilling modified truss head screws at **6 in./12 in.**	■ Screws pulled out of studs; Screws rupture edge of sheathing; Many screws loose after test is stopped. ■ Screws pulled out of stud along top track and at vertical edges adjacent to top track; Screws also pulled out interior stud close to the top track.

Table 4. Continued

Test no.	Assembly description	Behavior of wall assembly
AISI-E1 AISI-E2	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	■ Corners break off; Relatively stable resistance when test stopped. ■ Corners break off; Relatively stable resistance when test stopped.
AISI-E3 AISI-E4	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	■ Corners break off at the bottom track; Relatively stable resistance when test stopped. ■ Corners break off at bottom track; Relatively stable resistance when test stopped.
AISI-E5 AISI-E6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	■ Buckling in chord stud at web knockout (non-loaded edge)-flanges on the non-sheathed face. ■ Buckling in chord studs at web knockout.
AISI-F1 AISI-F2	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	■ Screws pulled out of studs along top track and along vertical edges close to top track. ■ Screws pulled out of studs along top track and along vertical edges close to top track.
AISI-F3 AISI-F4	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1/2 in. self-drilling modified truss head screws at **2 in./12 in.**	■ Buckling in the chord stud (loaded edge); Distortion of chord flange (non-loaded side). ■ Buckling in chord stud close to top knockout; Many screws along the top edge loose after test stopped.

Table 5. Strength and displacement capacities for statically loaded wall assemblies

Test no.	Assembly description	Maximum load, plf.	Displacement at maximum load, in.
AISI-1 AISI-2	***Structural system***: 4-1/2-in. 20 ga. Flat strap X-bracing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets	626 720	0.709 0.696
AISI-3 AISI-4	***Structural system***: 7-1/2-in. 20 ga. Flat strap X-bracing one side ***Framing***: 18 ga. 3-1/2 in. studs and 20 ga. 3-1/2-in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets	864 891	0.722 0.917
AISI-5 AISI-6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	982 1070	2.624 *DCDT removed @ 2.411*
AISI-7 AISI-8	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	1848 1802	*DCDT removed @ 3.105* *DCDT removed @ 2.421*
AISI-9 AISI-10	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	648 426	*DCDT removed @ 2.201* *DCDT removed @ 1.894*
AISI-11 AISI-12	***Structural system***: 25 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	496 486	*DCDT removed @ 2.194* *DCDT removed @ 1.886*
AISI-13 AISI-14	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	926 1055	*DCDT removed @ 2.086* 1.973
AISI-15 AISI-16	***Structural system***: 25 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	466 500	1.137 1.459

Table 6. Strength and displacement capacities for cyclically loaded wall assemblies

Test no.	Assembly description	Maximum +ve load, plf.	Displacement at maximum +ve load, in.	Maximum -ve load, plf.	Displacement at maximum -ve load, in.
AISI-A1 AISI-A2	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	1711 1714	2.4 2.0	-1855 -1822	2.4 2.0
AISI-A3 AISI-A4	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	2389 2014	2.8 2.8	-2156 -2202	2.8 2.4
AISI-A5 AISI-A6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	1476 1514	1.6 1.6	-1522 -1582	1.6 1.6
AISI-A7 AISI-A8	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	1860 1949	2.0 2.0	-2331 -2095	2.0 2.0
AISI-B1 AISI-B2	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screw at **6 in./12 in.**	844 920	1.6 2.0	-796 -1008	1.6 2.0
AISI-B3 AISI-B4	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 16 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point screws at **6 in./12 in.**	824 920	1.2 1.2	-872 -1003	1.2 1.2
AISI-C1 AISI-C2	***Structural system***: 4-1/2 in. 20 ga. flat strap X-bracing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws (see note 5)	826 771	1.2 1.2	-841 -849	1.2 1.2
AISI-C3	***Structural system***: 7-1/2 in. 20 ga. flat strap X-bracing one side	637	0.6	-978	1.0

AISI-C4	***Framing:*** 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment:*** No. 8-18 x ½ in. self-drilling modified truss head screws (see note 6)	783	0.6	-960	1.0
AISI-D1 AISI-D2	***Structural System:*** 25 ga. steel sheathing one side ***Framing:*** 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment:*** No. 8-18 x ½ in. self-drilling modified truss head screws at **6 in./12 in.**	346 407	1.2 1.0	-452 -364	1.2 0.8

Table 6. Continued

Test no.	Assembly description	Maximum +ve load, plf.	Displacement at maximum +ve load, in.	Maximum -ve load, plf.	Displacement at maximum -ve load, in.
AISI-E1 AISI-E2	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	688 713	2.8 2.8	-682 -804	2.8 2.8
AISI-E3 AISI-E4	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	1107 1127	2.8 2.8	-1097 -1173	2.8 2.8
AISI-E5 AISI-E6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	1840 1340	2.8 1.6	-1684 -1633	2.4 2.0
AISI-F1 AISI-F2	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	895 951	2.0 1.6	-1132 -1036	2.0 1.6
AISI-F3 AISI-F4	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1/2 in. self-drilling modified truss head screws at **2 in./12 in.**	1188 1304	2.0 2.0	-1067 -1127	2.0 1.6

Table 7. Average strength and displacement capacities for statically loaded wall assemblies

Test no.	Assembly description	Average maximum load, plf.	Displacement at average maximum load, in.
AISI-1 AISI-2	***Structural system***: 4-1/2-in. 20 ga. Flat strap X-bracing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets	673	0.702
AISI-3 AISI-4	***Structural system***: 7-1/2-in. 20 ga. Flat strap X-bracing one side ***Framing***: 18 ga. 3-1/2 in. studs and 20 ga. 3-1/2-in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws to corner gussets	877	0.819
AISI-5 AISI-6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	1026	2.624 *DCDT removed @ 2.411*
AISI-7 AISI-8	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	1825	*DCDT removed @ 3.105* *DCDT removed @ 2.421*
AISI-9 AISI-10	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	537	*DCDT removed @ 2.201* *DCDT removed @ 1.894*
AISI-11 AISI-12	***Structural system***: 25 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	491	*DCDT removed @ 2.194* *DCDT removed @ 1.886*
AISI-13 AISI-14	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	990	*DCDT removed @ 2.086* 1.973
AISI-15 AISI-16	***Structural system***: 25 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws **at 6 in./12 in.**	483	1.298

Table 8. Average strength and displacement capacities for cyclically loaded wall assemblies

Test no.	Assembly description	Average of maximum +ve/-ve load, plf.	Displ. at average of maximum +ve/-ve load, in.	Average maximum load, plf.	Displ. at average maximum load, in.
AISI-A1 AISI-A2	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	1783 1768	2.4 2.0	1775	2.2
AISI-A3 AISI-A4	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	2272 2108	2.8 2.6	2190	2.7
AISI-A5 AISI-A6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **3 in./12 in.**	1499 1548	1.6 1.6	1523	1.6
AISI-A7 AISI-A8	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 18 ga. 3-1/2-in. back-to-back chord studs; 20 ga. 3-1/2 in. interior studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	2095 2022	2.0 2.0	2058	2.0
AISI-B1 AISI-B2	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 18 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screw at **6 in./12 in.**	820 964	1.6 2.0	892	1.8
AISI-B3 AISI-B4	***Structural system***: 15/32-in. APA rated plywood sheathing one side ***Framing***: 16 ga. 3-1/2-in. studs; 20 ga. 3-1/2 in. tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point screws at **6 in./12 in.**	848 961	1.2 1.2	904	1.2
AISI-C1 AISI-C2	***Structural system***: 4-1/2 in. 20 ga. flat strap X-bracing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws (see	833 810	1.2 1.2	821	1.2

	note 5)				
AISI-C3 AISI-C4	***Structural system:*** 7-1/2 in. 20 ga. flat strap X-bracing one side ***Framing:*** 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment:*** No. 8-18 x ½ in. self-drilling modified truss head screws (see note 6)	807 871	0.8 0.8	839	0.8
AISI-D1 AISI-D2	***Structural System:*** 25 ga. steel sheathing one side ***Framing:*** 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment:*** No. 8-18 x ½ in. self-drilling modified truss head screws at **6 in./12 in.**	399 385	1.2 0.9	392	1.0

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Table 8. Continued

Test no.	Assembly description	Average of maximum +ve/-ve load, plf.	Displ. at average of maximum +ve/-ve load, in.	Average maximum load, plf.	Displ. at average maximum load, in.
AISI-E1 AISI-E2	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **6 in./12 in.**	685 758	2.8 2.8	721	2.8
AISI-E3 AISI-E4	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **4 in./12 in.**	1102 1150	2.8 2.8	1126	2.8
AISI-E5 AISI-E6	***Structural system***: 7/16-in. APA rated OSB sheathing one side ***Framing***: 20 ga. 3-1/2-in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1 in. sharp point flat head screws at **2 in./12 in.**	1762 1486	2.6 1.8	1624	2.2
AISI-F1 AISI-F2	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x ½ in. self-drilling modified truss head screws at **4 in./12 in.**	1013 993	2.0 1.6	1003	1.8
AISI-F3 AISI-F4	***Structural system***: 22 ga. steel sheathing one side ***Framing***: 20 ga. 3-1/2 in. studs and tracks; studs at 24 in. on center ***Attachment***: No. 8-18 x 1/2 in. self-drilling modified truss head screws at **2 in./12 in.**	1127 1215	2.0 1.8	1171	1.9

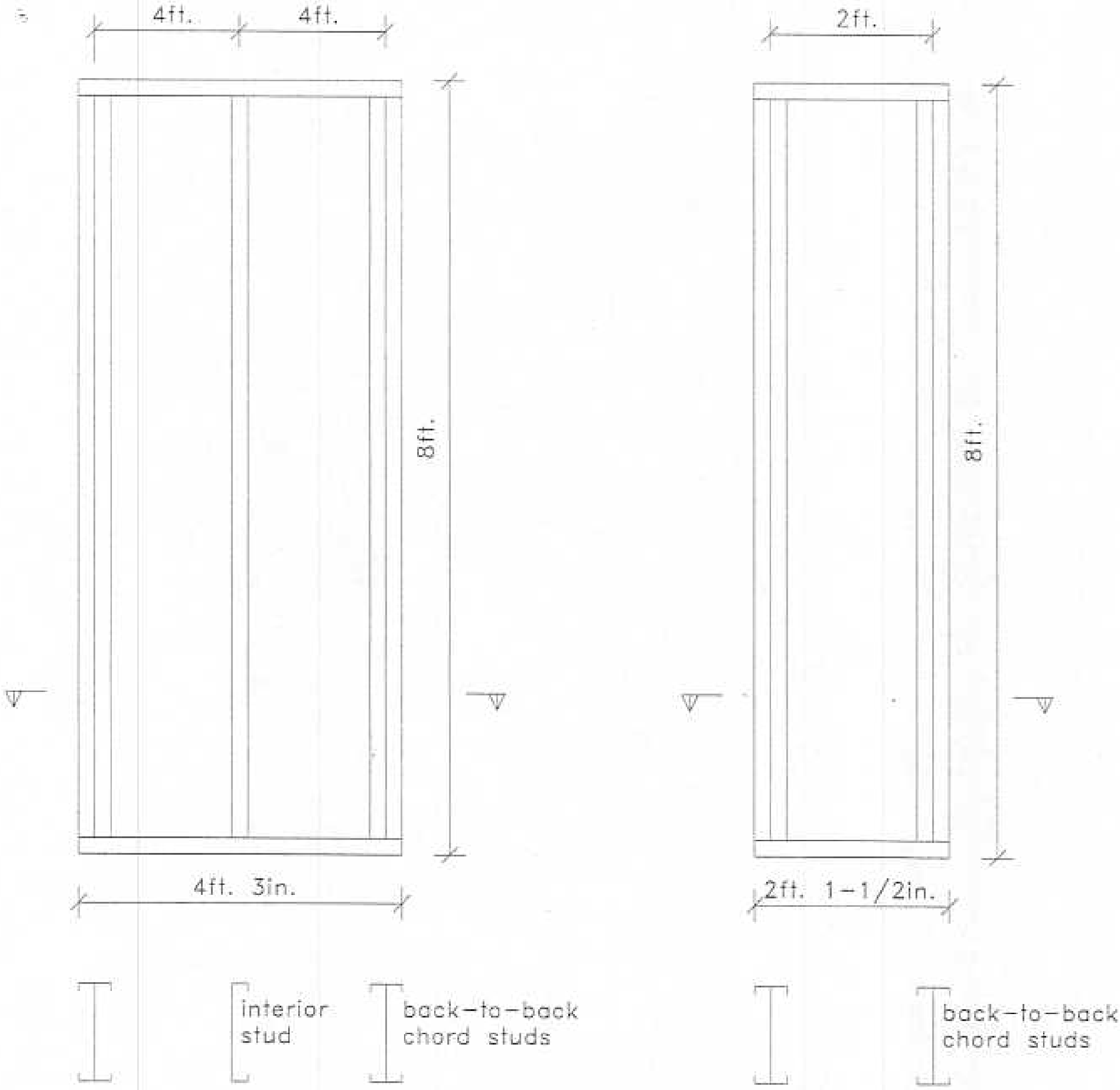


Figure 1a. Framing configuration for wall assemblies

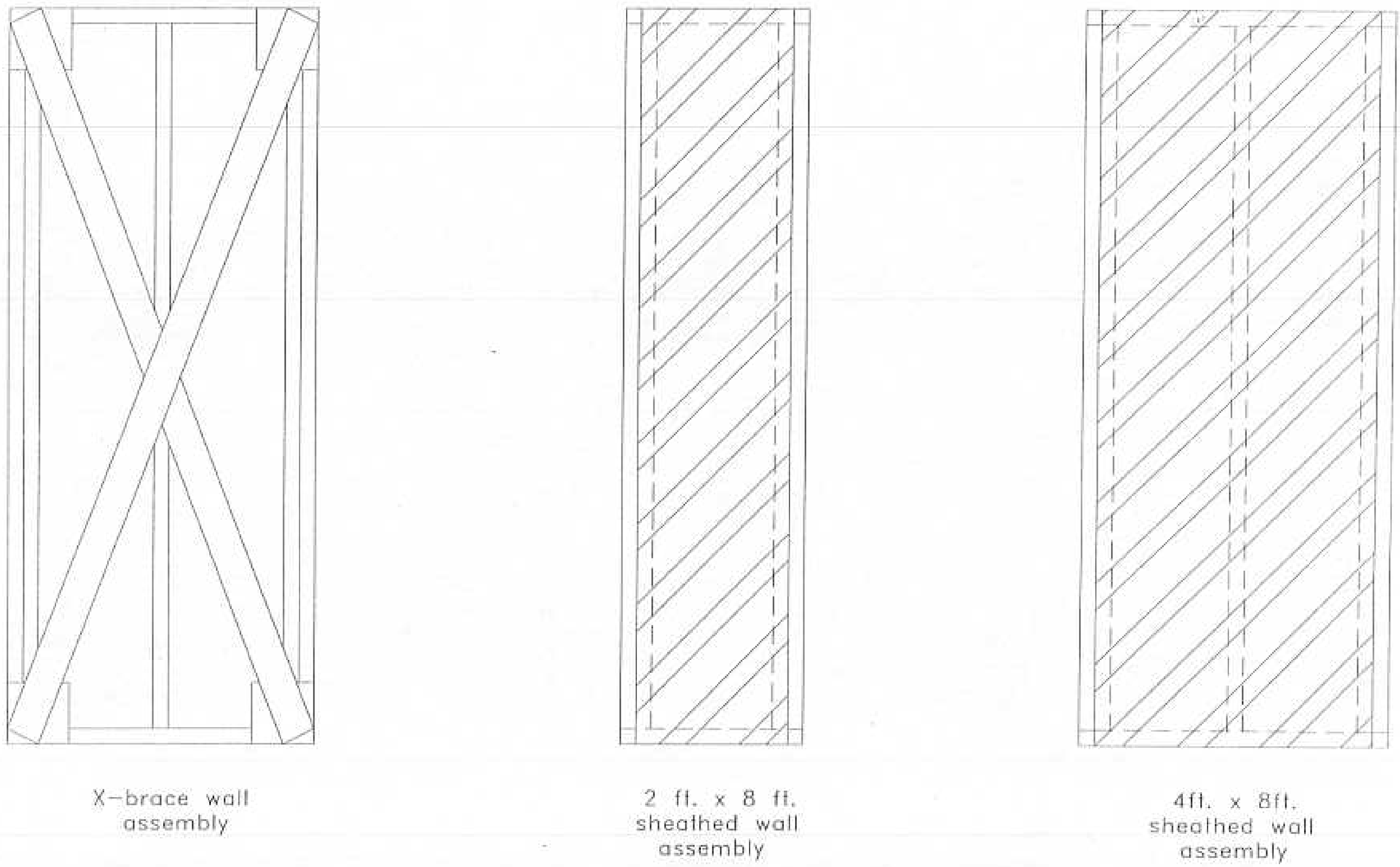


Figure 1b. Wall assembly configurations

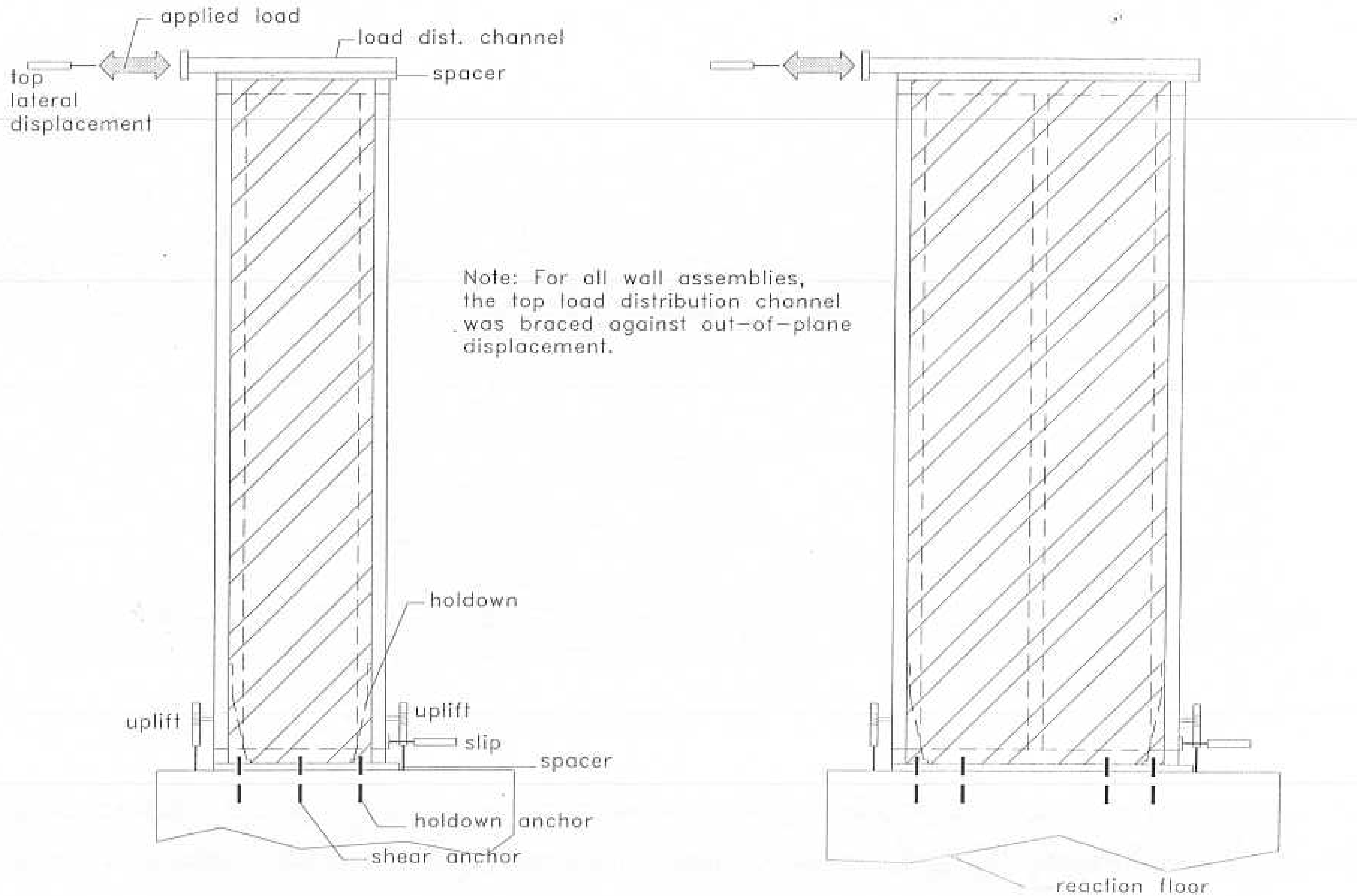
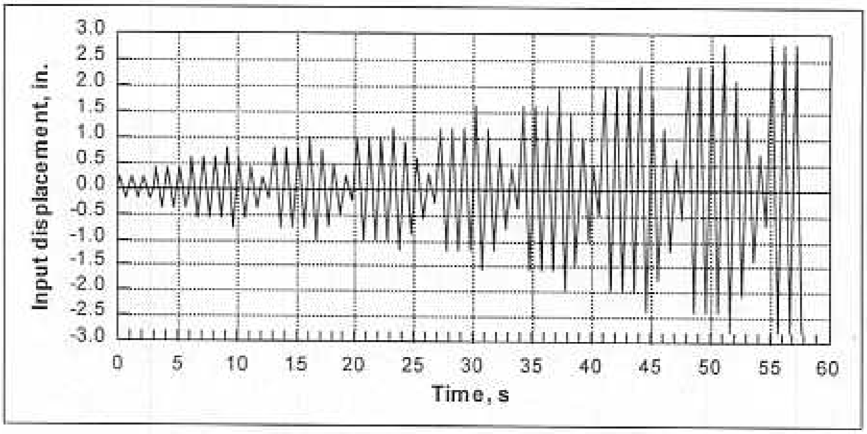


Figure 2. Overall test setup



No. of Cycles	Input Displacement, in.
3	0.2
3	0.4
3	0.6
3	0.8
1	1.0
1	0.75
1	0.50
1	0.25
3	1.0
1	1.2
1	0.9
1	0.6
1	0.3
3	1.2
1	1.6
1	1.2
1	0.8
1	0.4

No. of Cycles	Input Displacement, in.
3	1.6
1	2.0
1	1.5
1	1.0
1	0.5
3	2.0
1	2.4
1	1.8
1	1.2
1	0.6
3	2.4
1	2.8
1	2.1
1	1.4
1	0.7
3	2.8

Figure 3. Cyclic test protocol

APPENDICES

APPENDIX A:

Load vs. Top of Wall Deflection--Static Tests

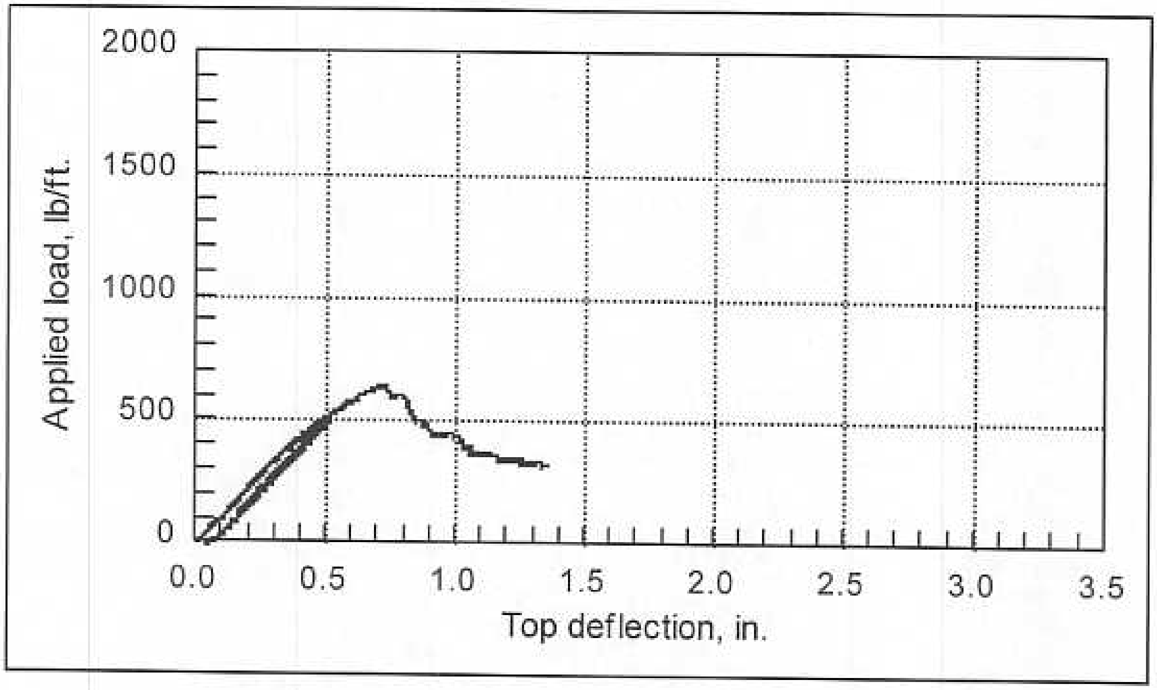


Figure A.1. Load vs. total top of wall deflection for AISI-1

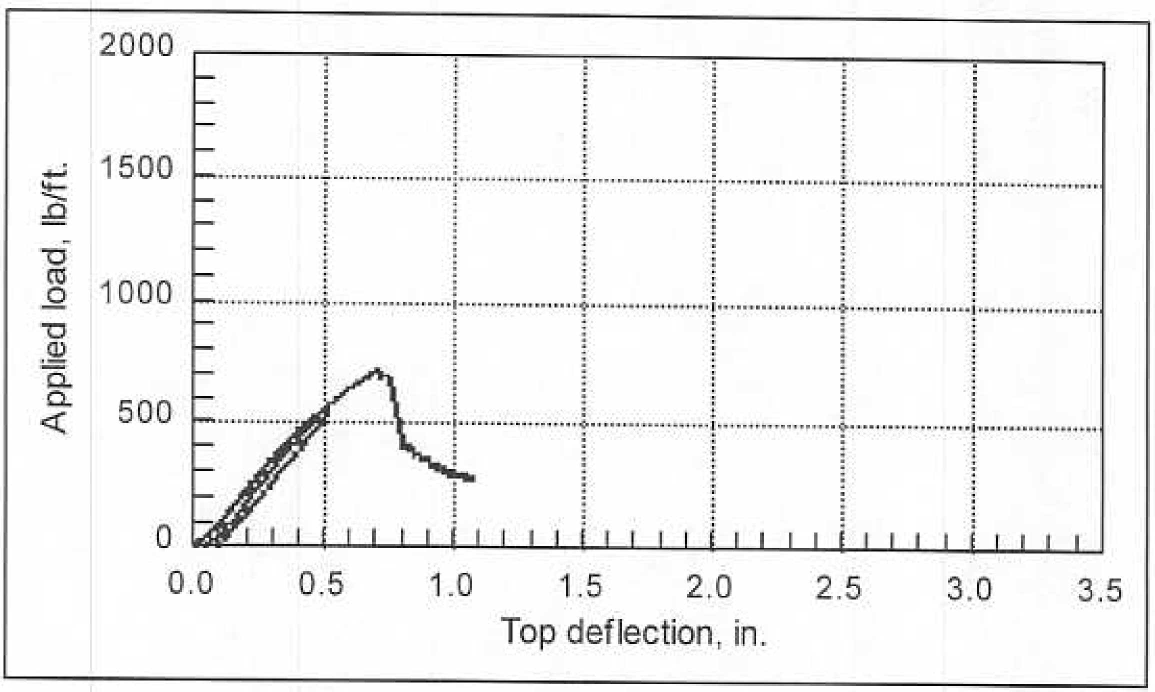


Figure A.2. Load vs. total top of wall deflection for AISI-2

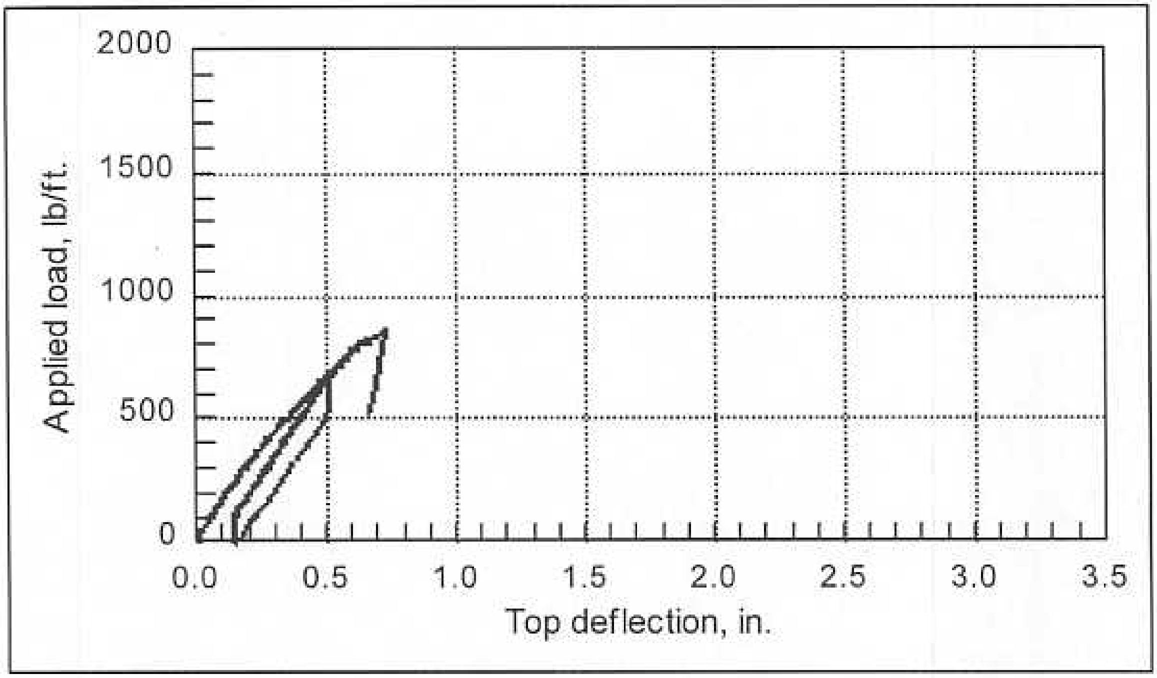


Figure A.3. Load vs. total top of wall deflection for AISI-3

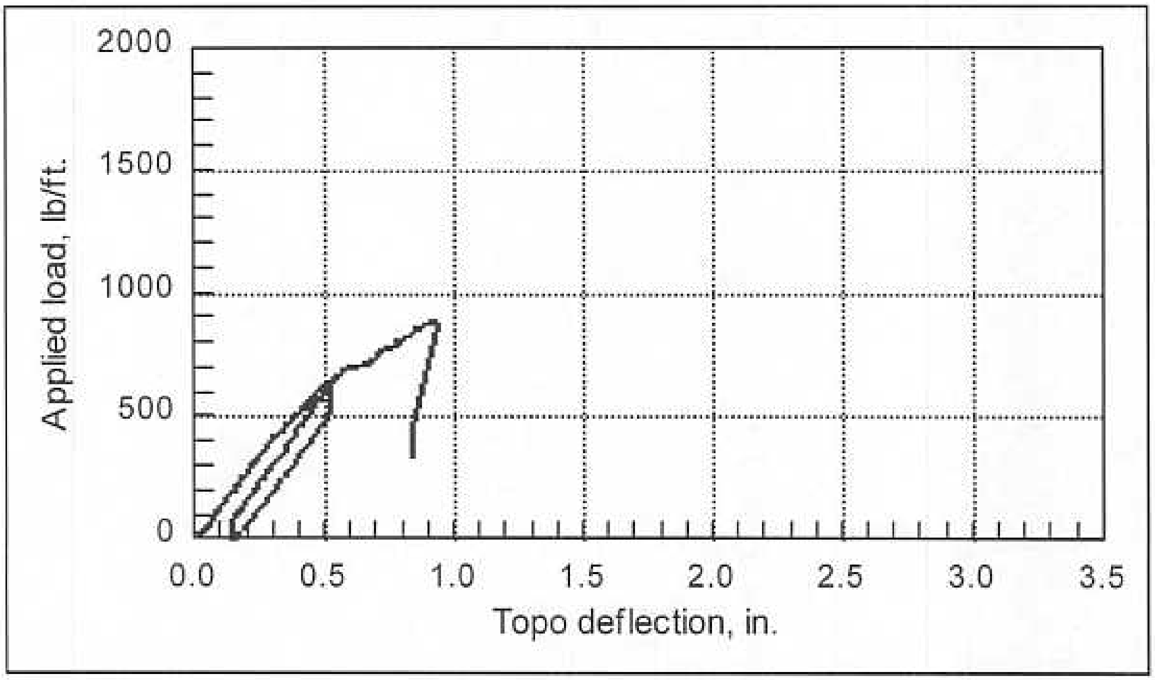


Figure A.4. Load vs. total top of wall deflection for AISI-4

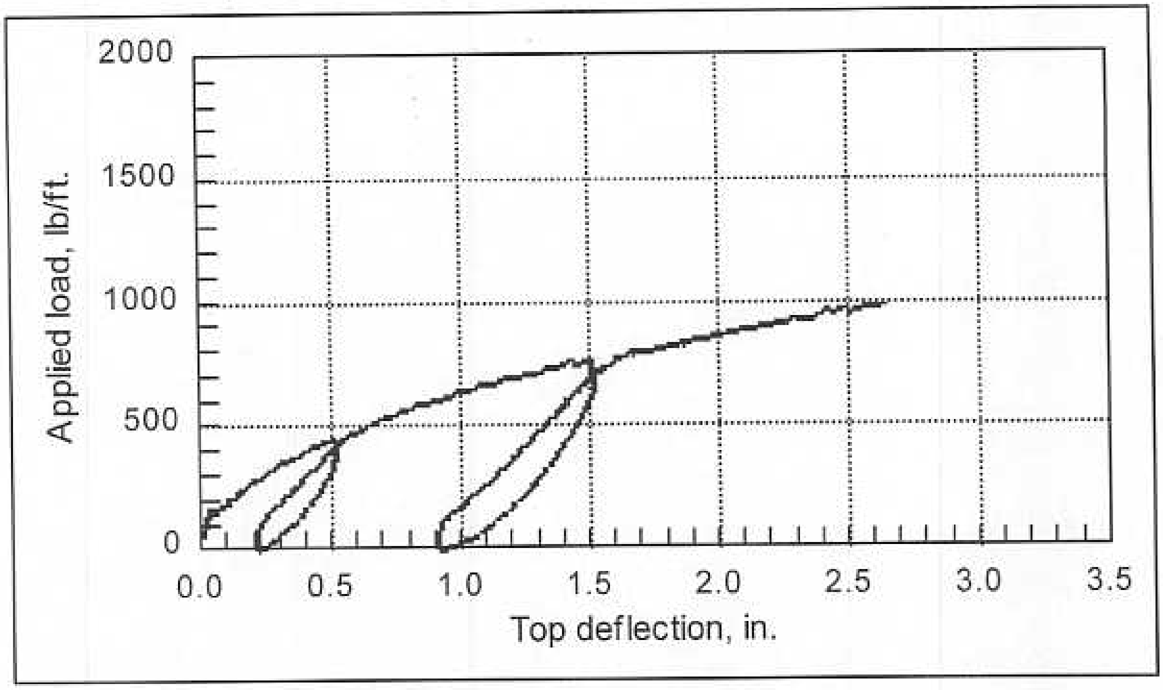


Figure A.5. Load vs. total top of wall deflection for AISI-5

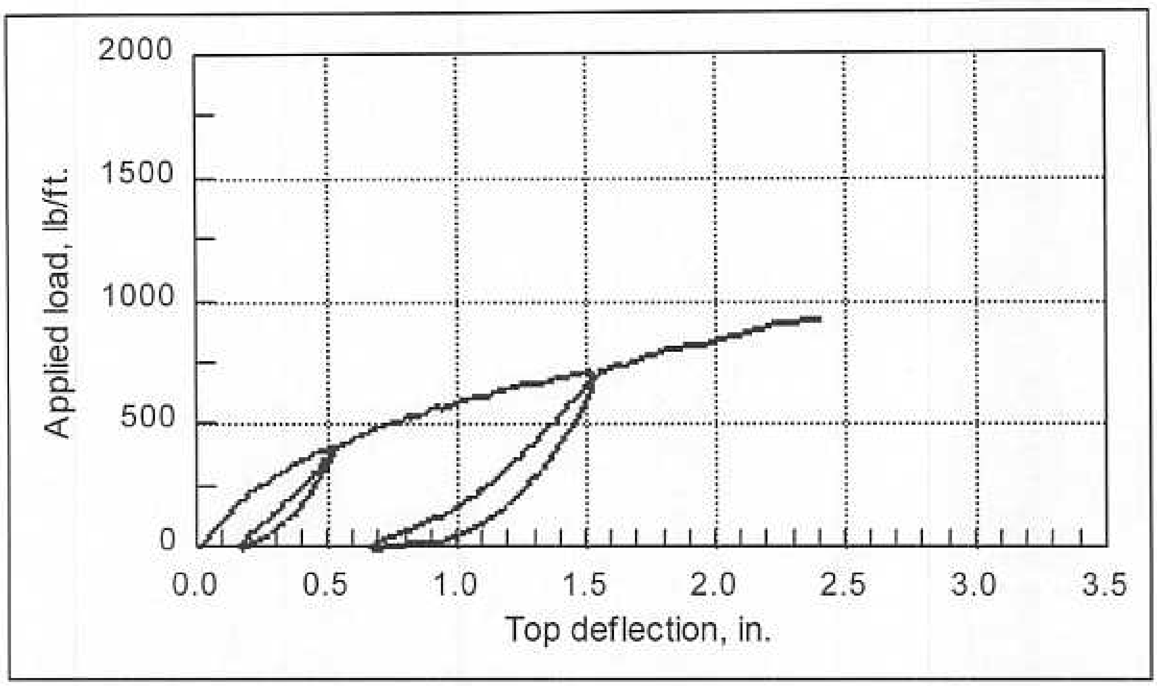


Figure A.6. Load vs. total top of wall deflection for AISI-6

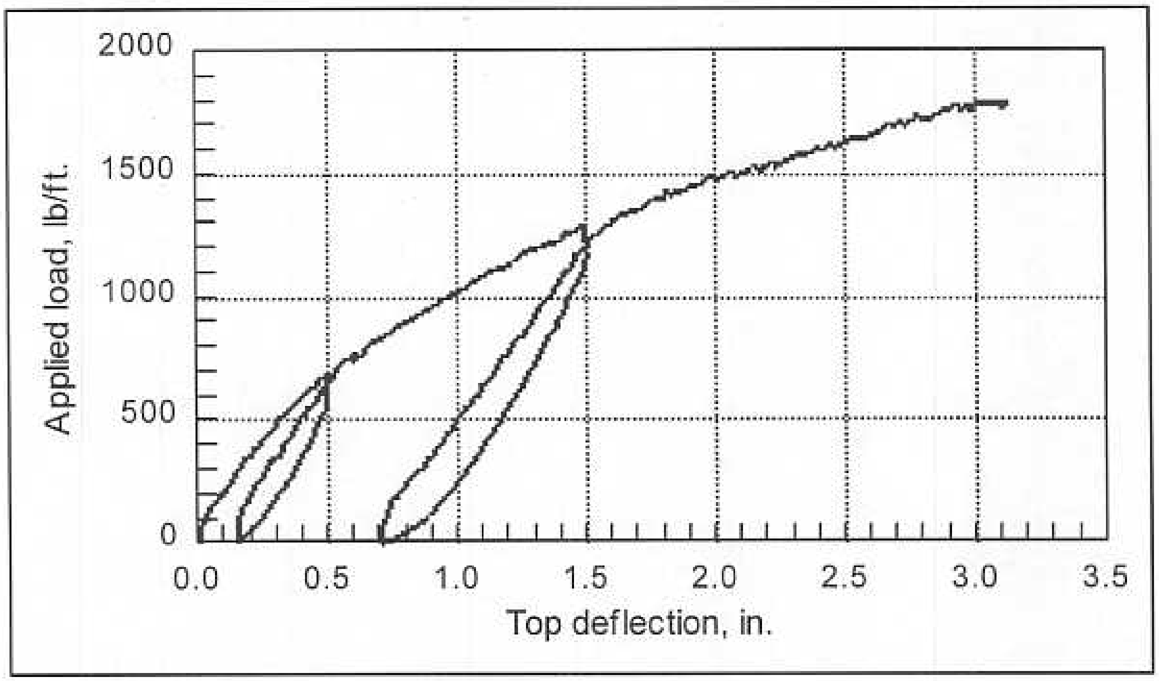


Figure A.7. Load vs. total top of wall deflection for AISI-7

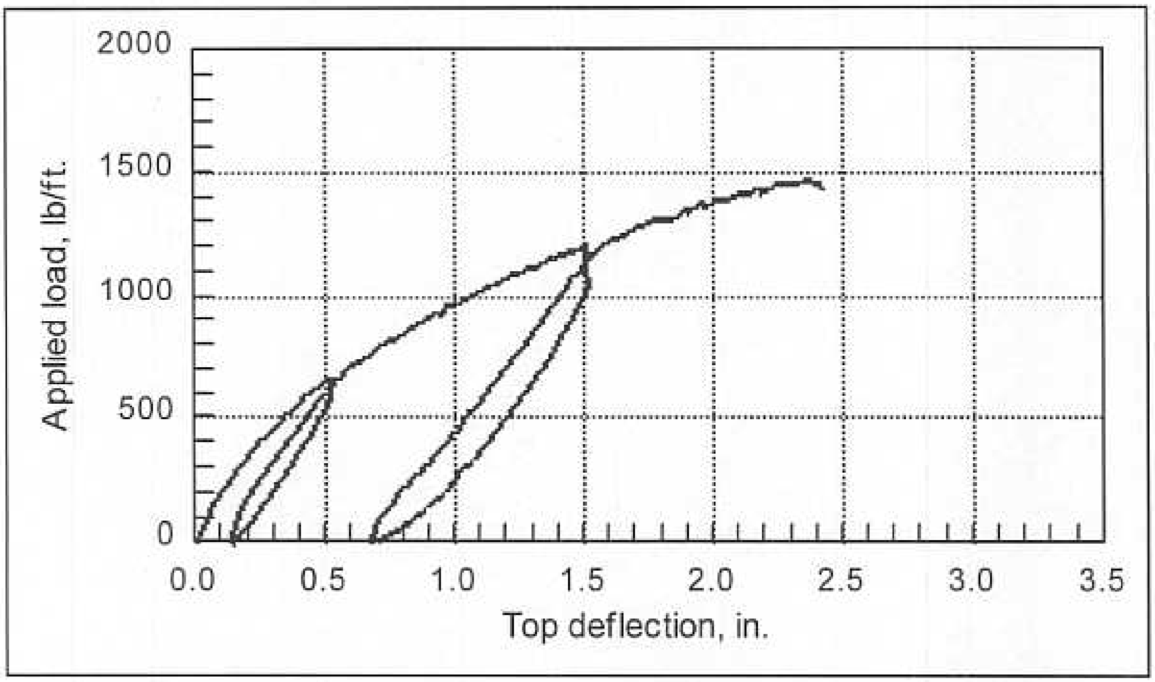


Figure A.8. Load vs. total top of wall deflection for AISI-8

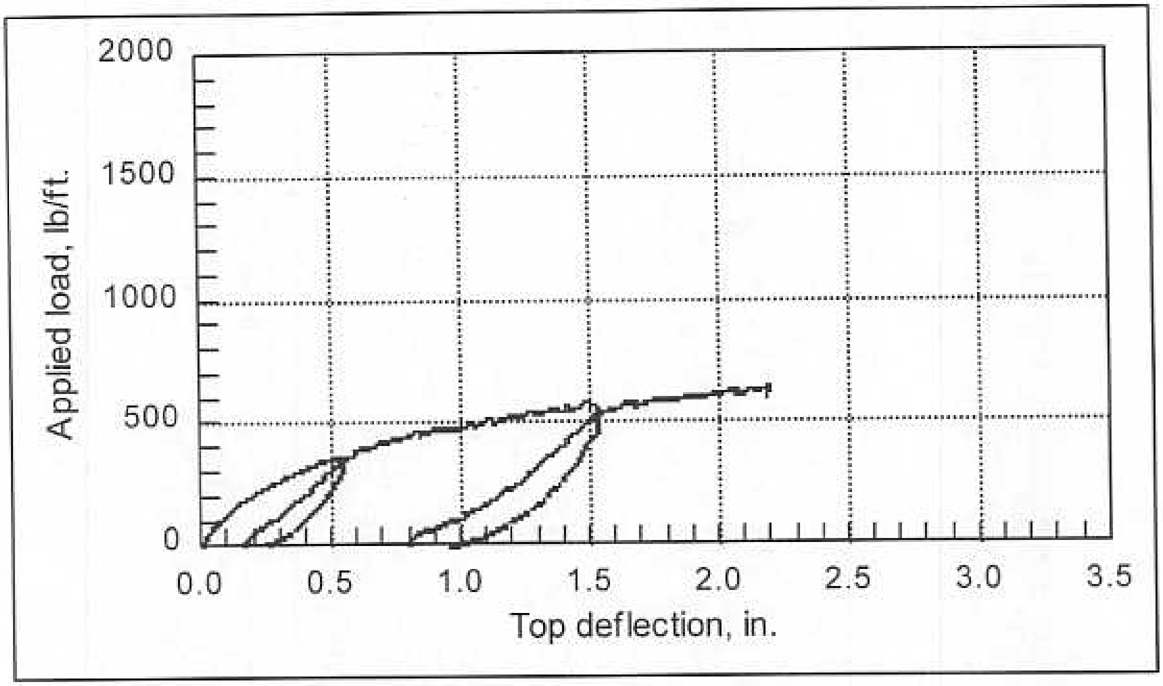


Figure A.9. Load vs. total top of wall deflection for AISI-9

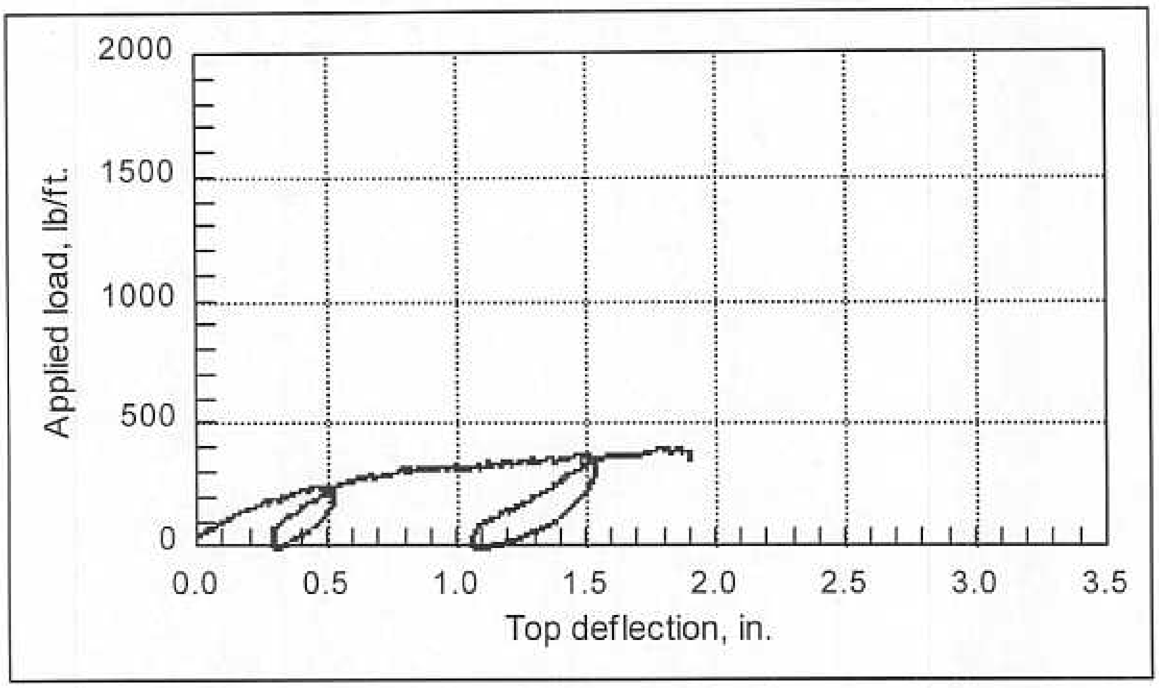


Figure A.10. Load vs. total top of wall deflection for AISI-10

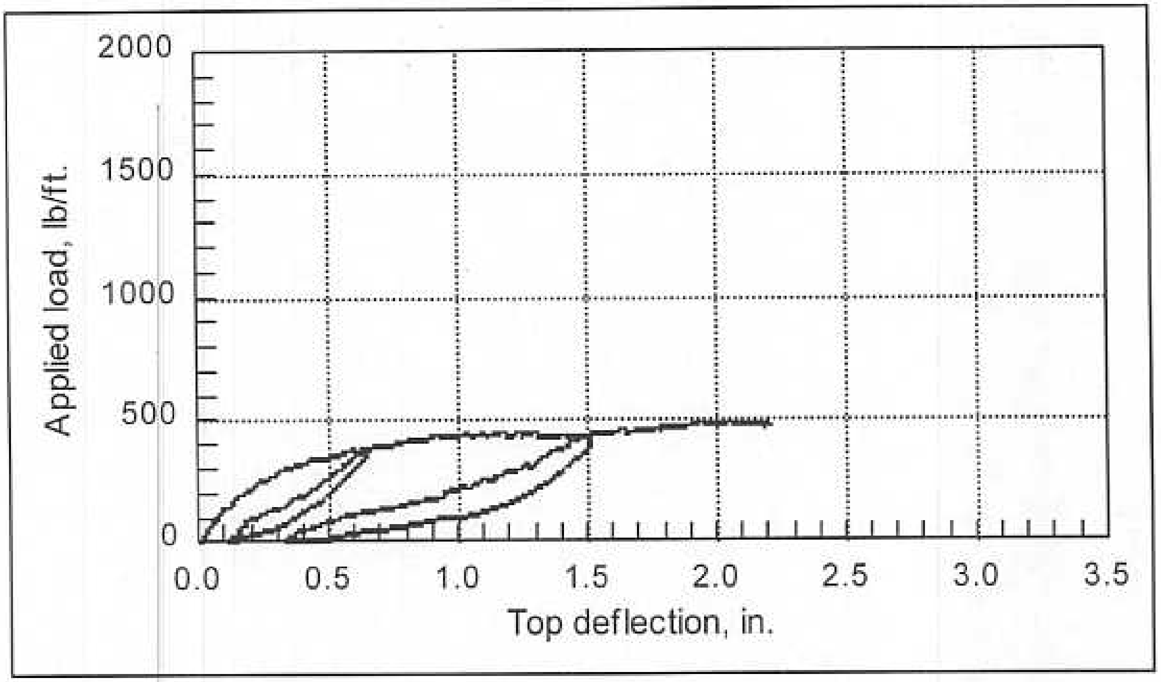


Figure A.11. Load vs. total top of wall deflection for AISI-11

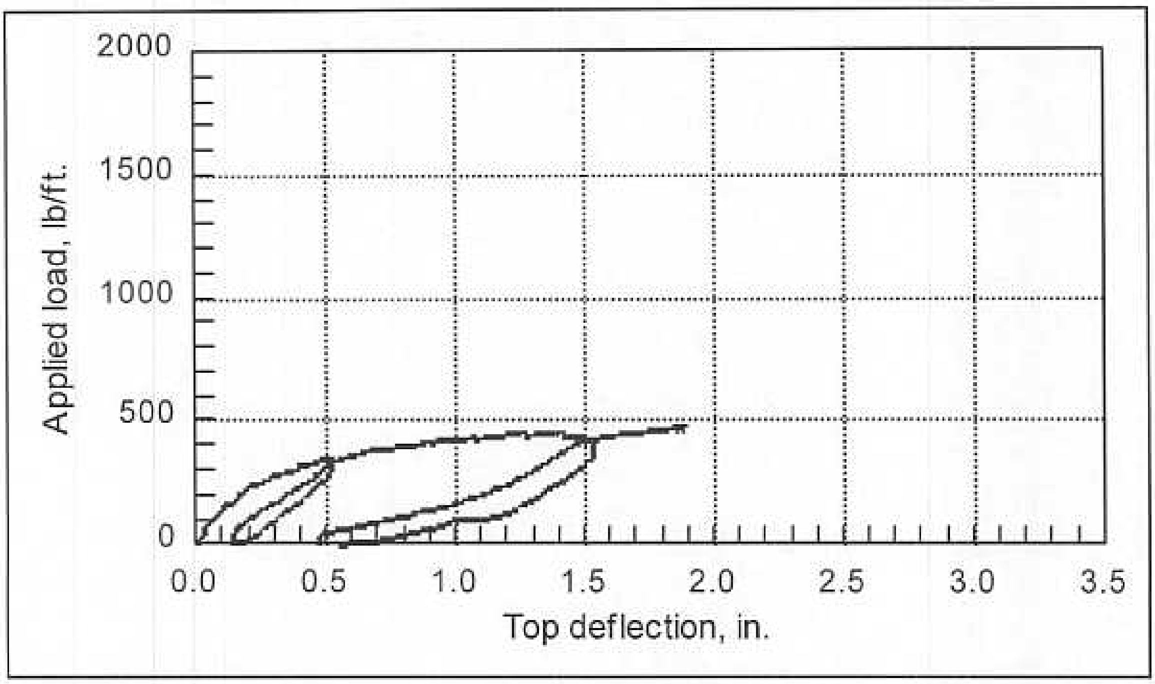


Figure A.12. Load vs. total top of wall deflection for AISI-12

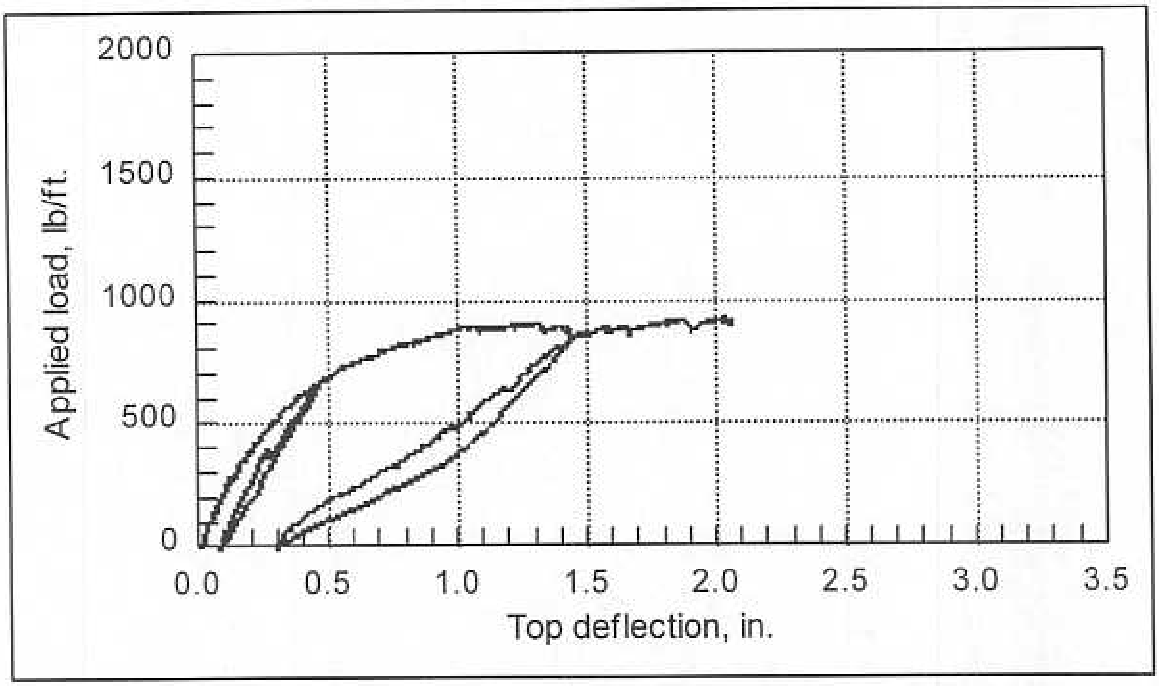


Figure A.13. Load vs. total top of wall deflection for AISI-13

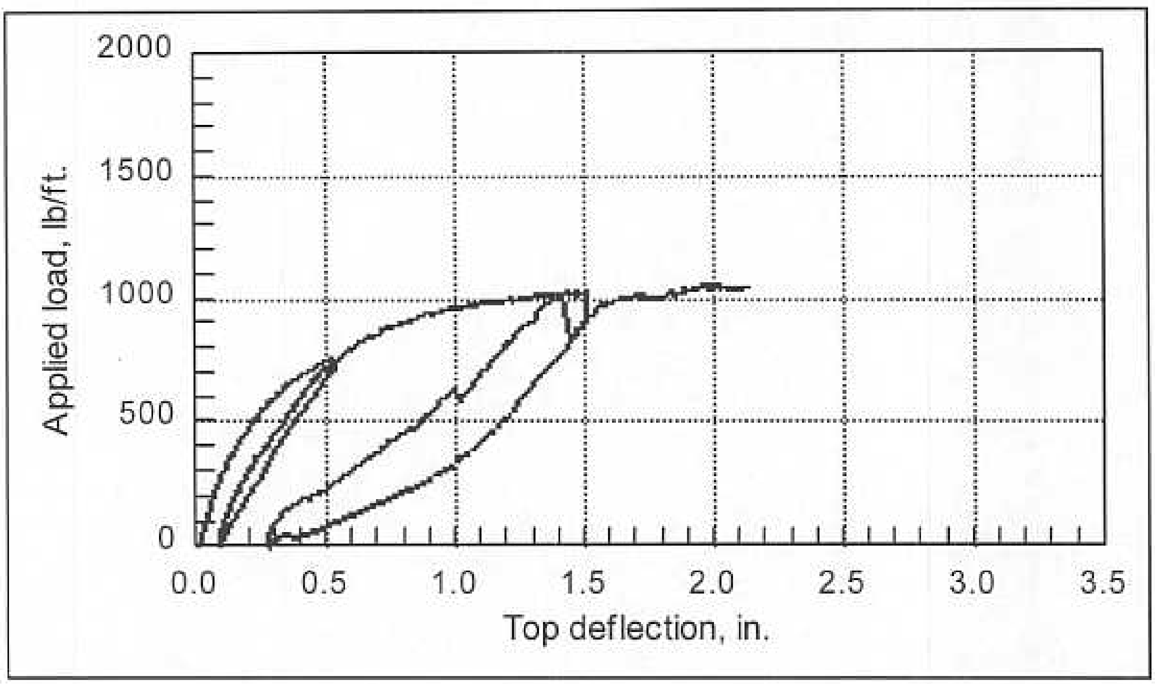


Figure A.14. Load vs. total top of wall deflection for AISI-14

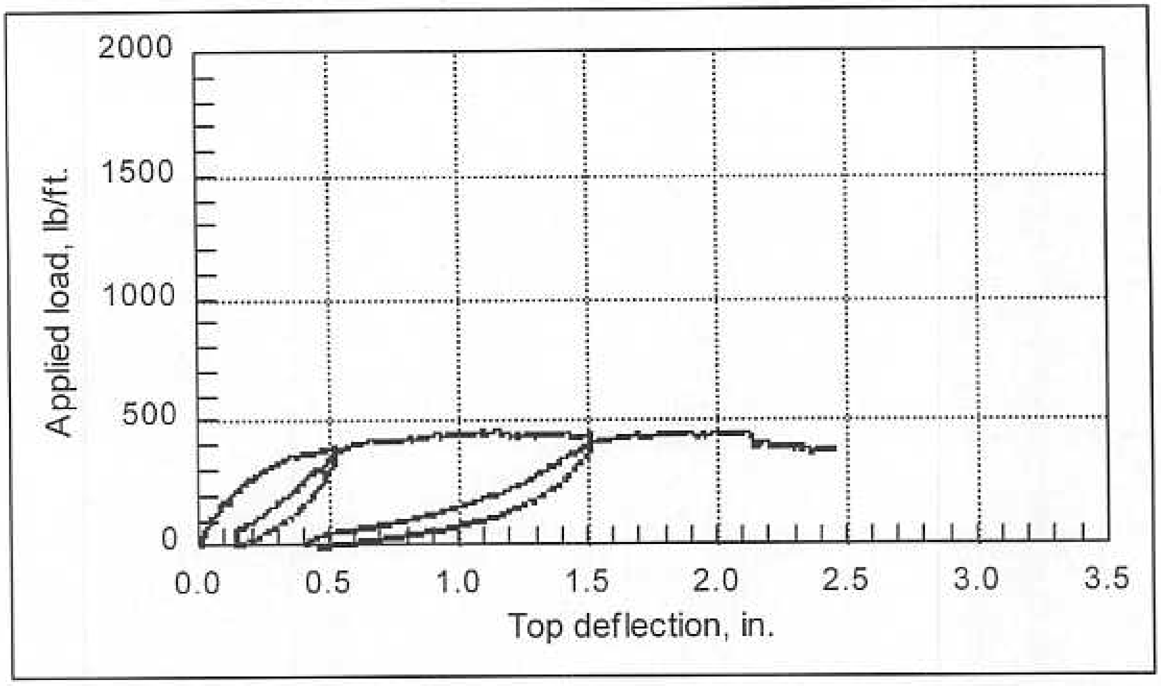


Figure A.15. Load vs. total top of wall deflection for AISI-15

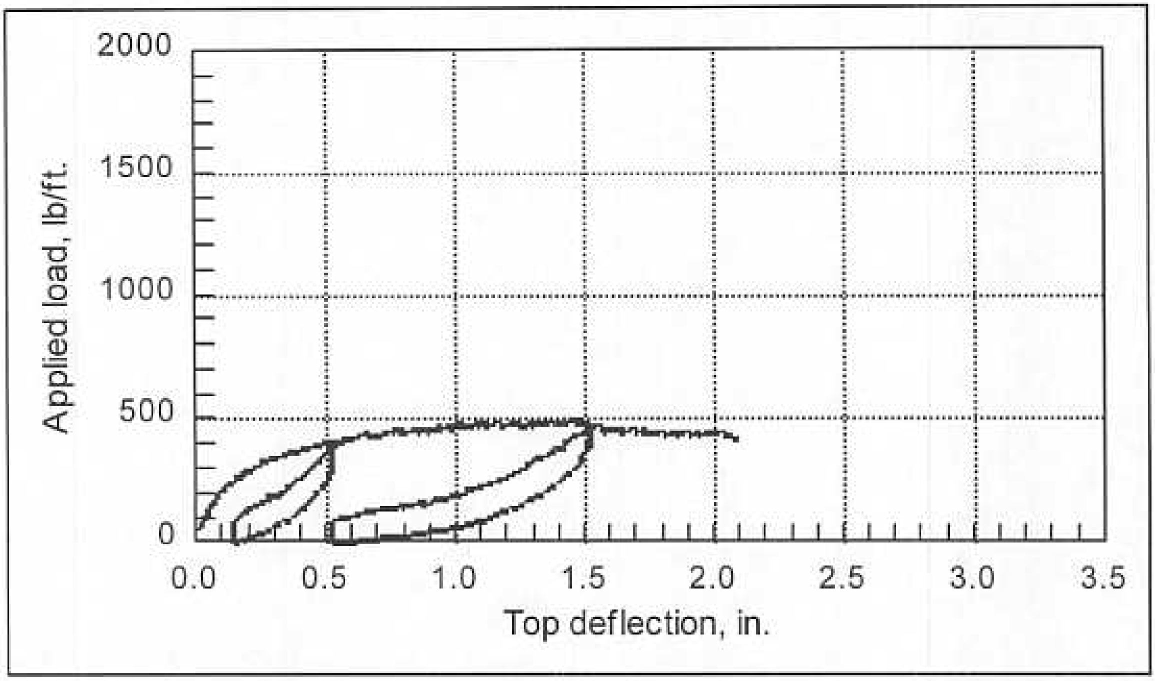


Figure A.16. Load vs. total top of wall deflection for AISI-16

APPENDIX B:

Load vs. Top of Wall Deflection--Cyclic Tests

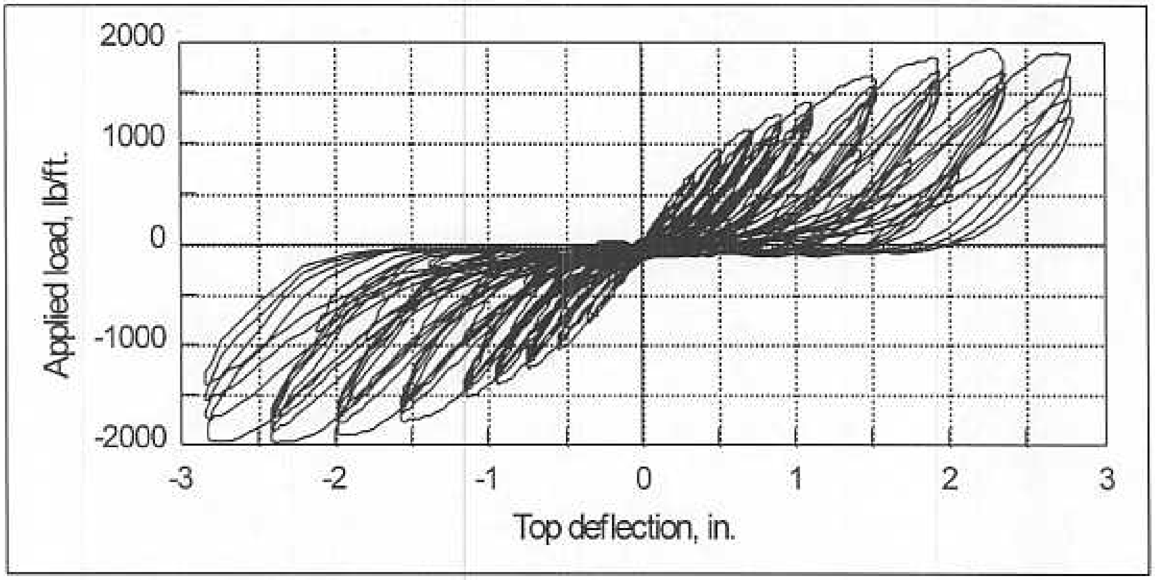


Figure B.1. Load vs. top of wall deflection for AISI-A1

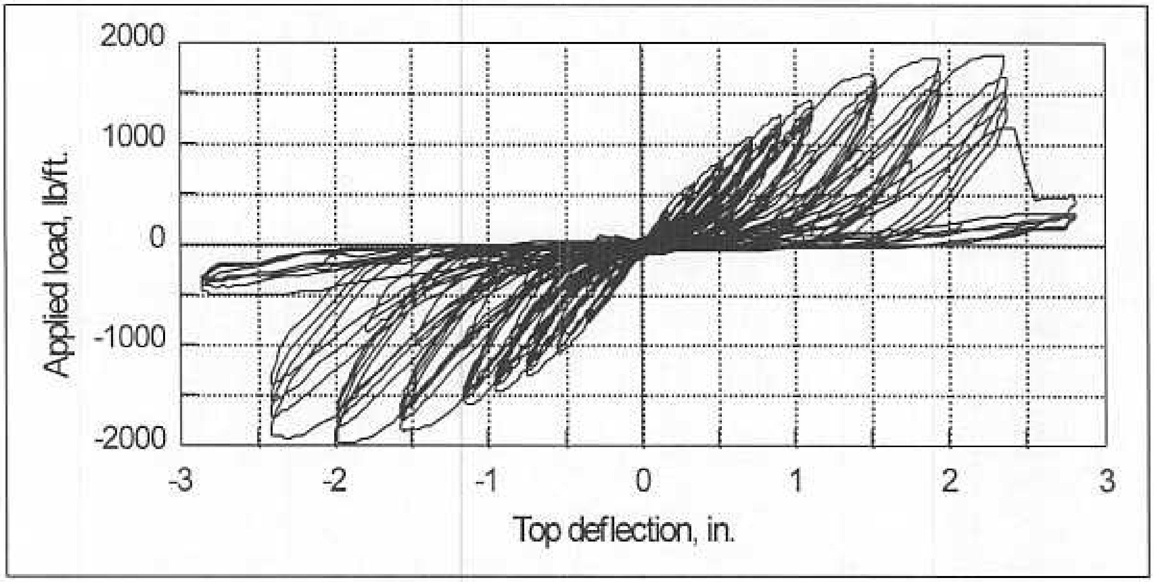


Figure B.2. Load vs. top of wall deflection for AISI-A2

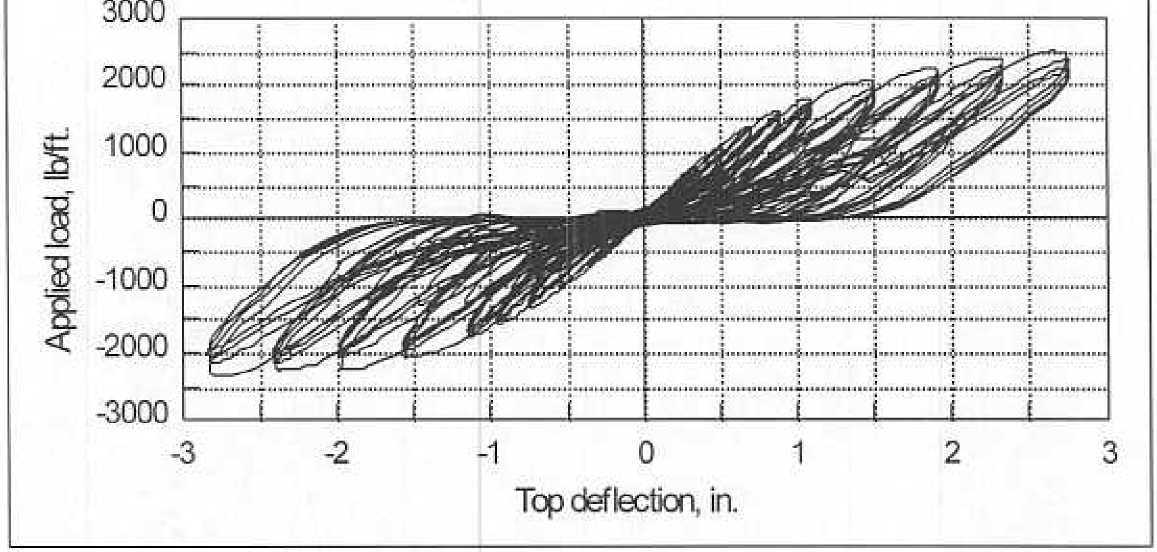


Figure B.3. Load vs. top of wall deflection for AISI-A3

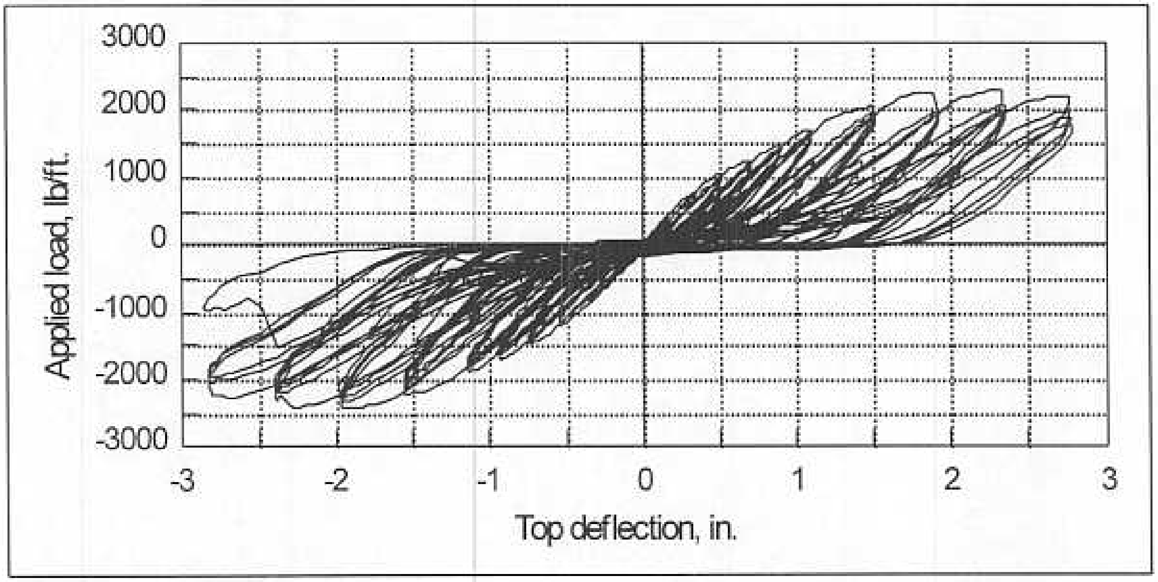


Figure B.4. Load vs. top of wall deflection for AISI-A4

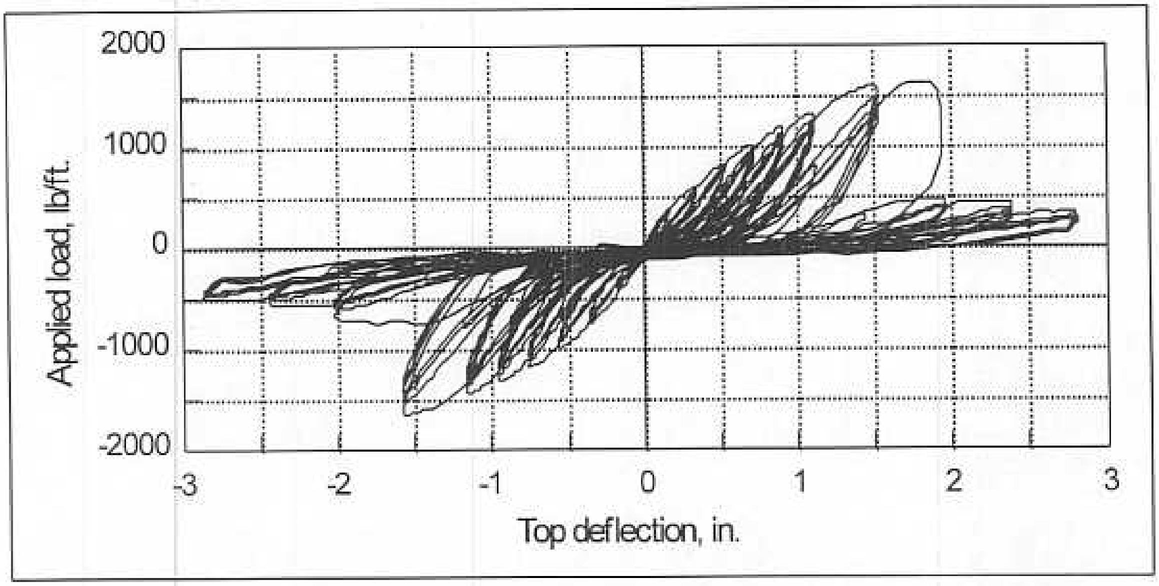


Figure B.5. Load vs. top of wall deflection for AISI-A5

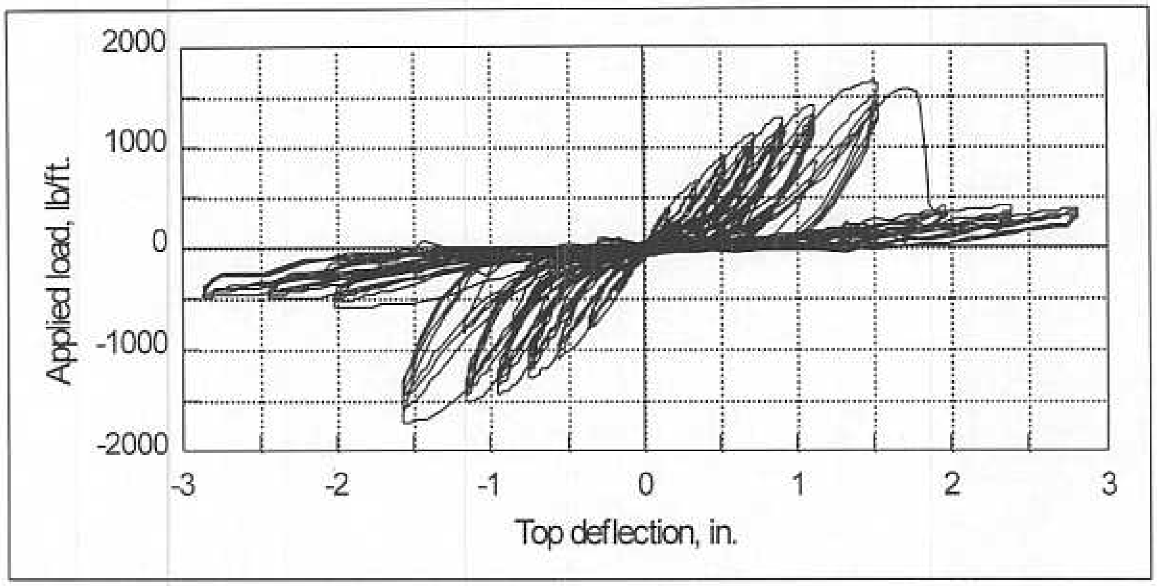


Figure B.6. Load vs. top of wall deflection for AISI-A6

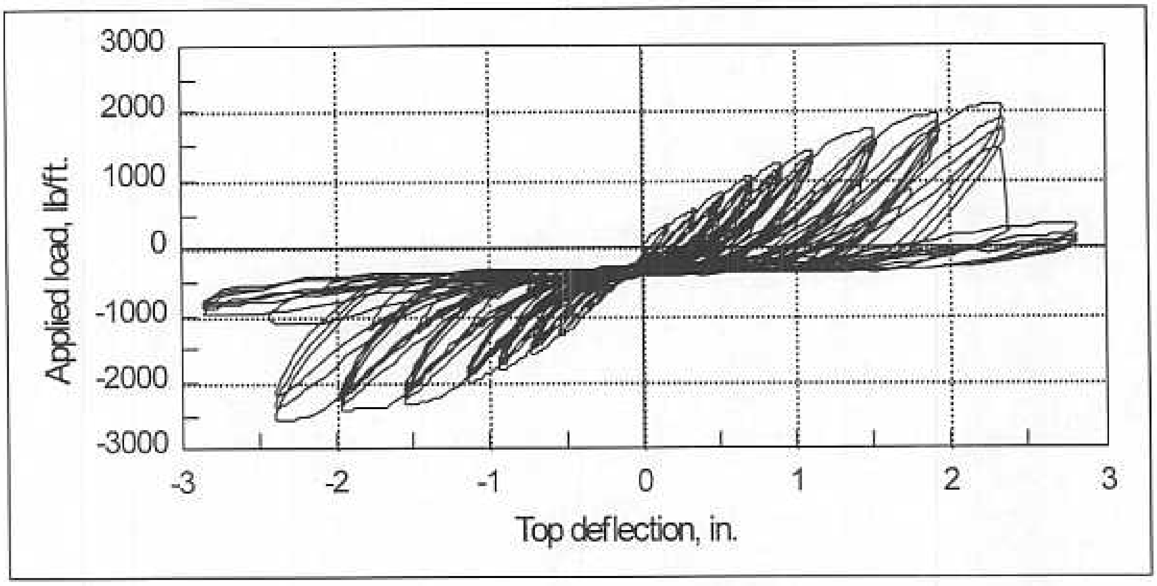


Figure B.7. Load vs. top of wall deflection for AISI-A7

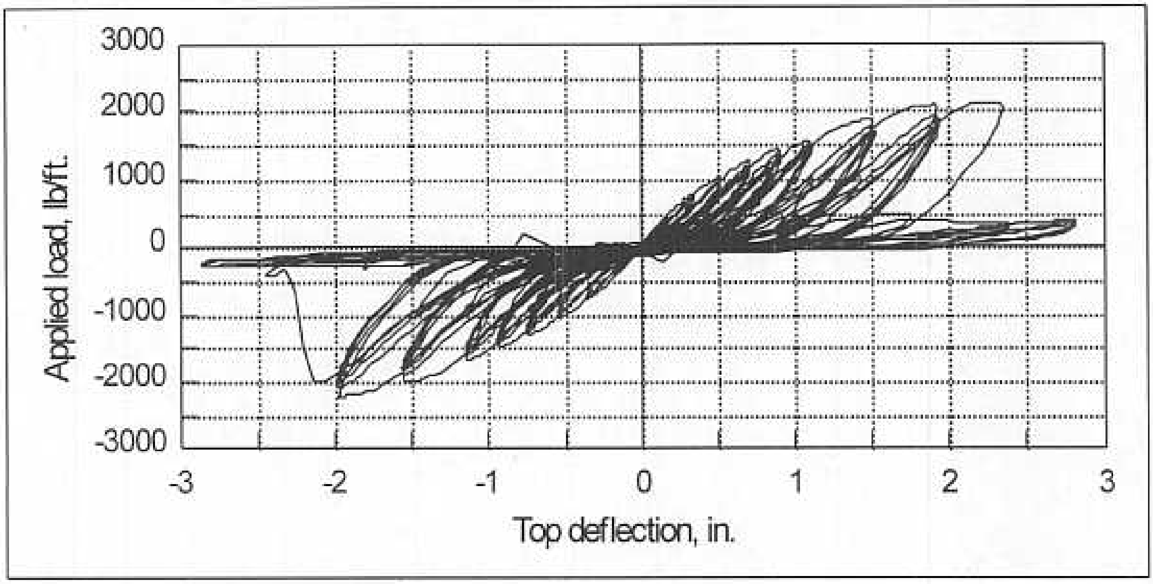


Figure B.8. Load vs. top of wall deflection for AISI-A8

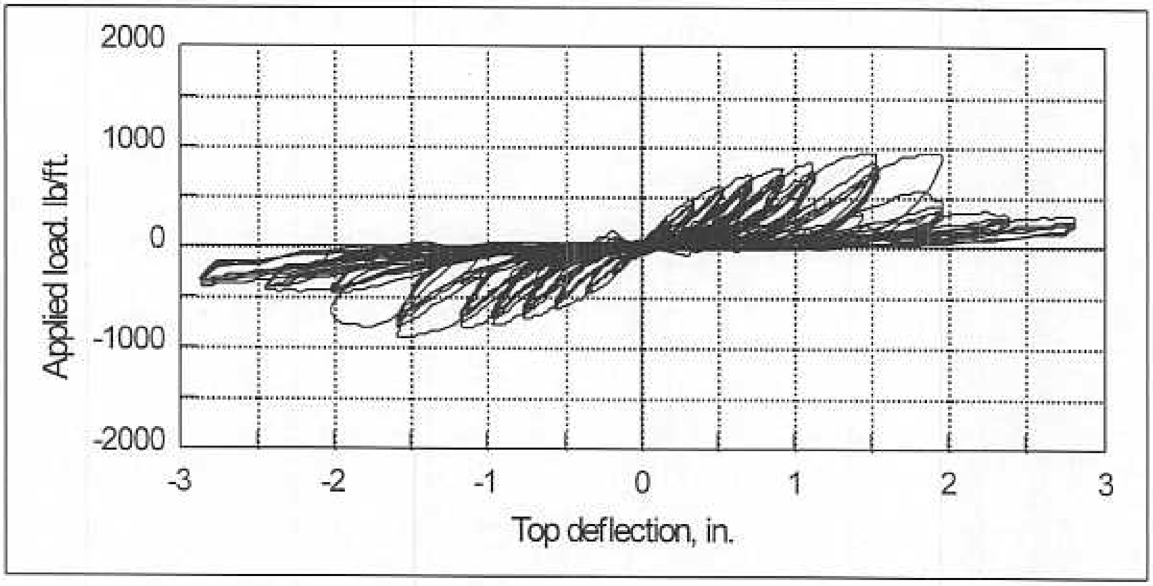


Figure B.9. Load vs. top of wall deflection for AISI-B1

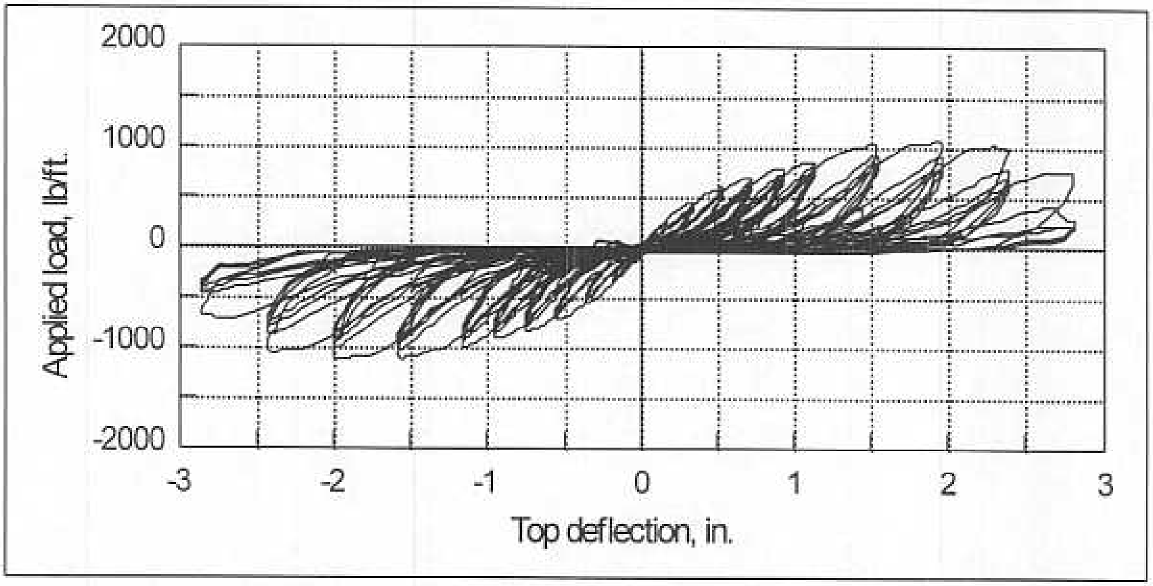


Figure B.10. Load vs. top of wall deflection for AISI-B2

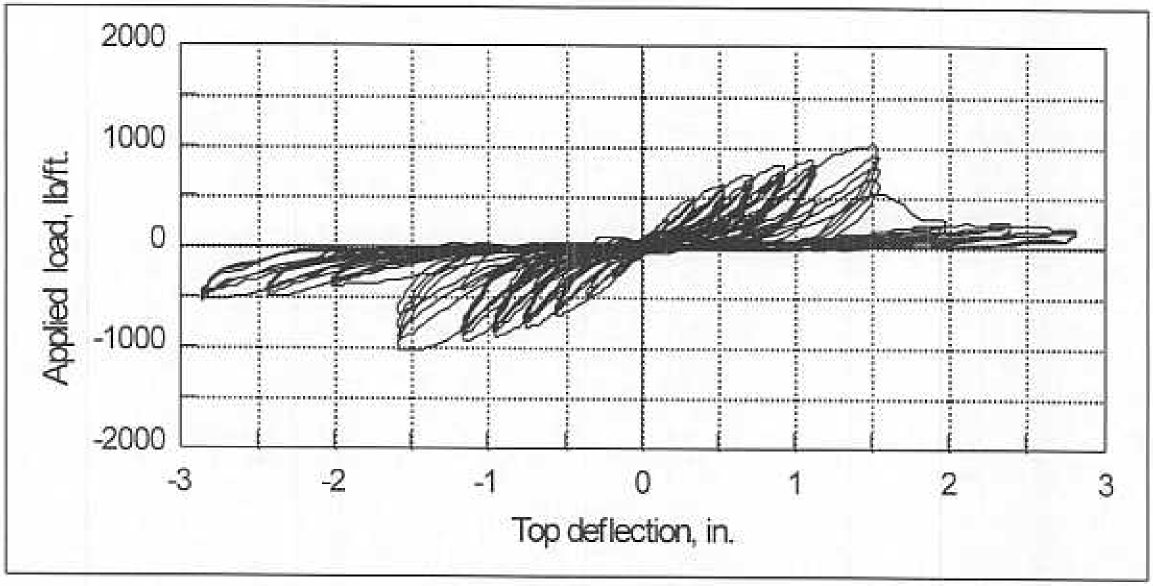


Figure B.11. Load vs. top of wall deflection for AISI-B3

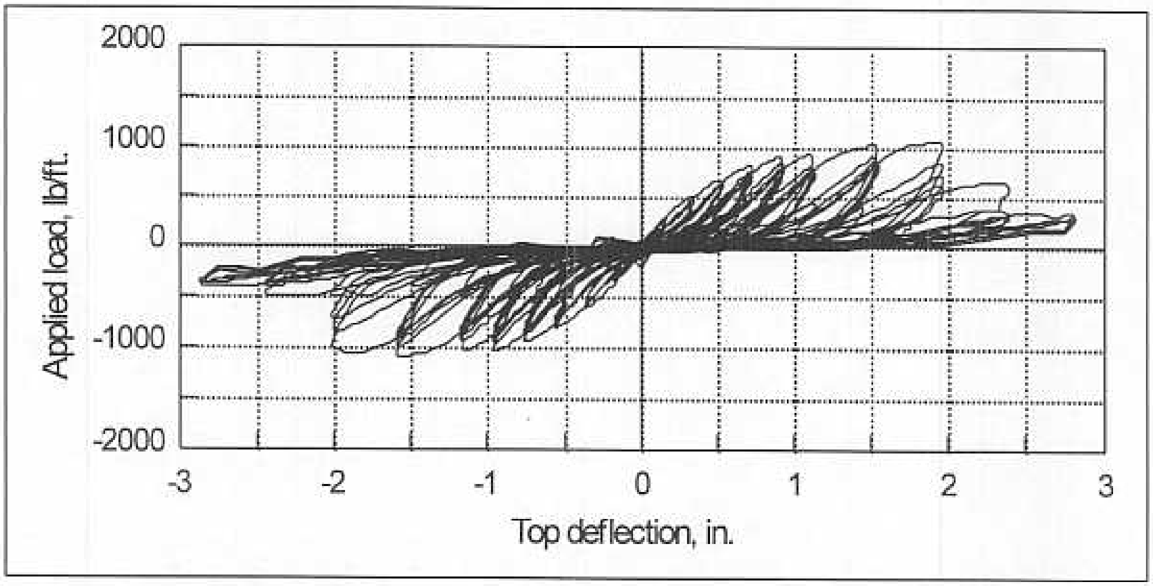


Figure B.12. Load vs. top of wall deflection for AISI-B4

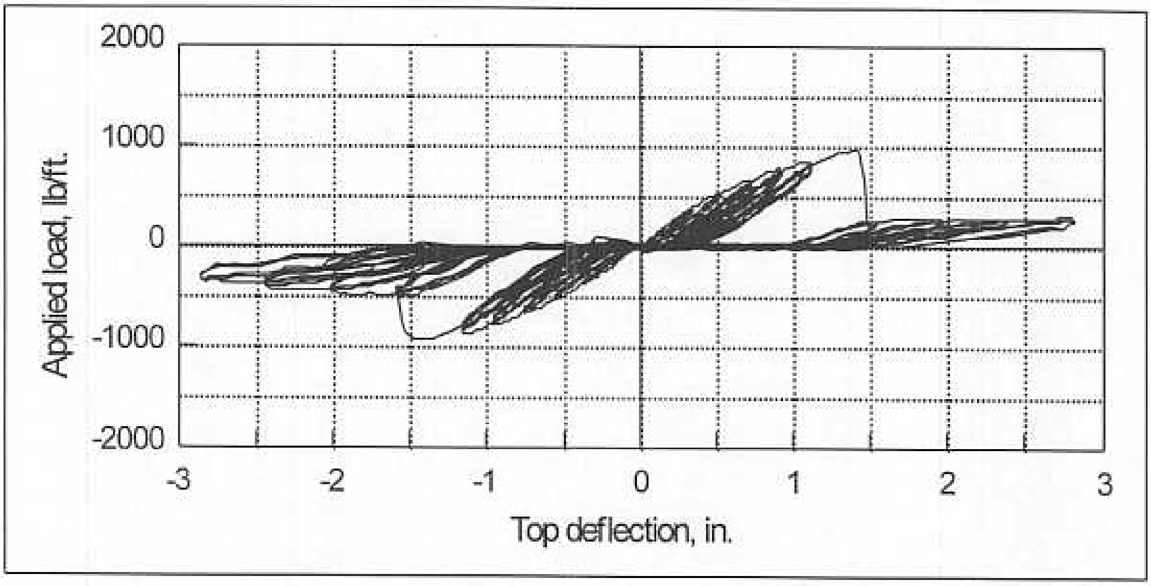


Figure B.13. Load vs. top of wall deflection for AISI-C1

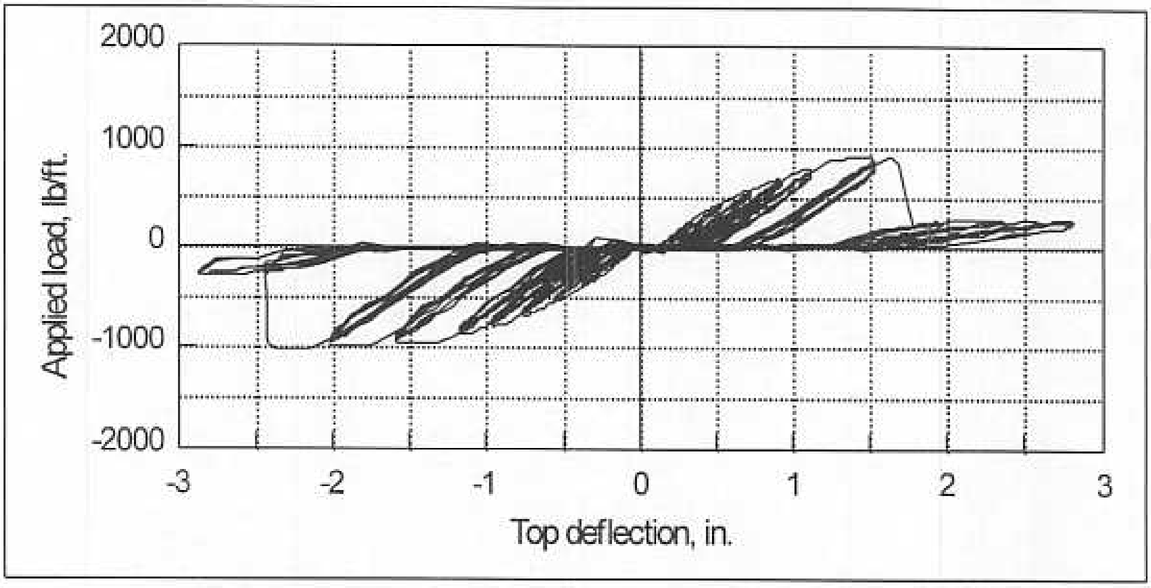


Figure B.14. Load vs. top of wall deflection for AISI-C2

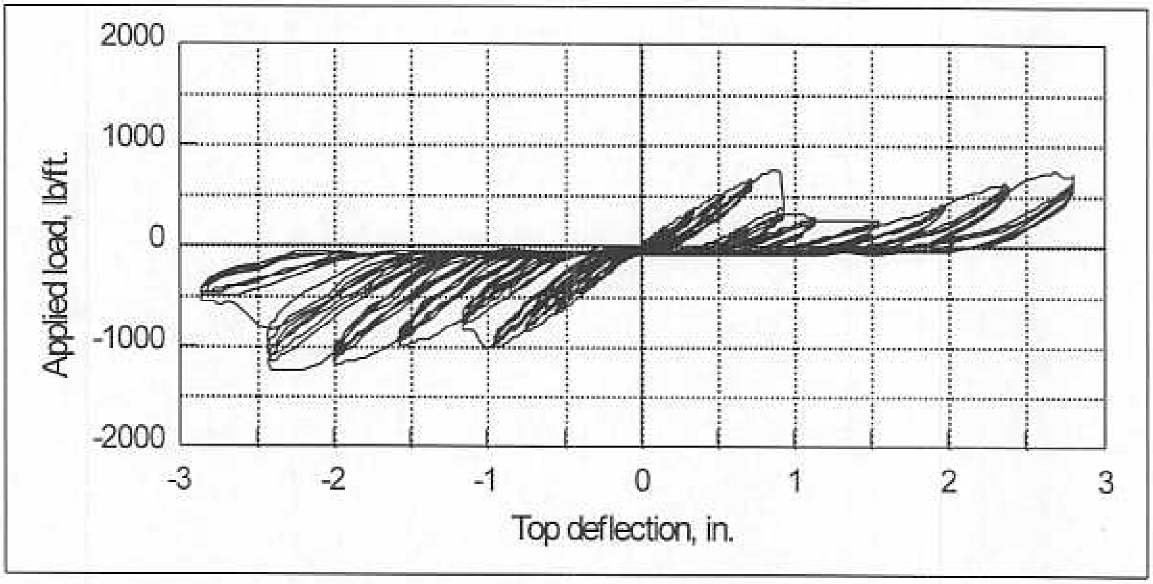


Figure B.15. Load vs. top of wall deflection for AISI-C3

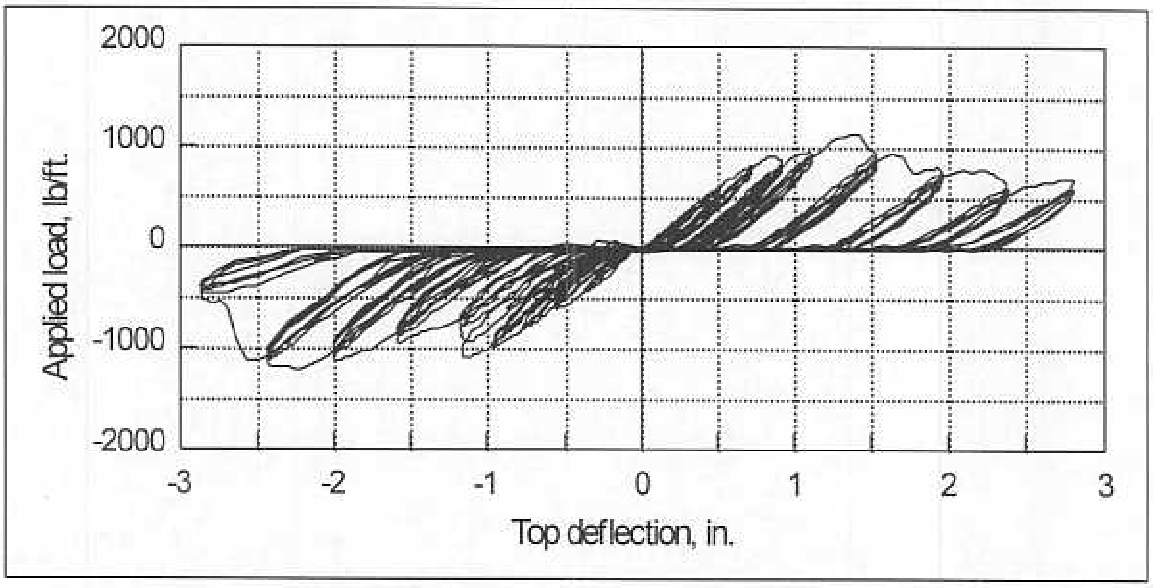


Figure B.16. Load vs. top of wall deflection for AISI-C4

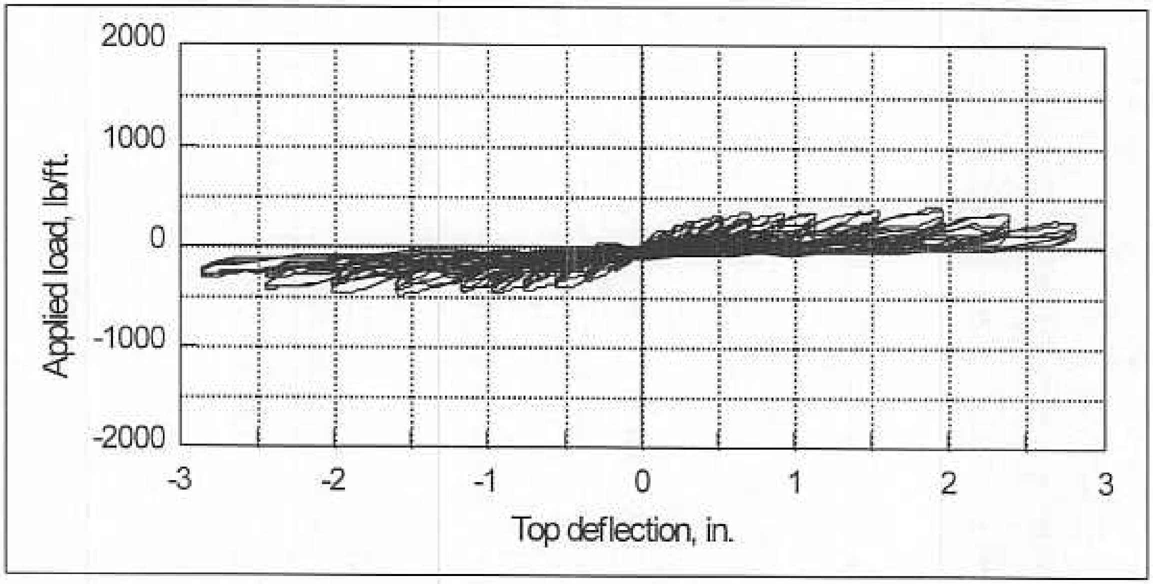


Figure B.17. Load vs. top of wall deflection for AISI-D1

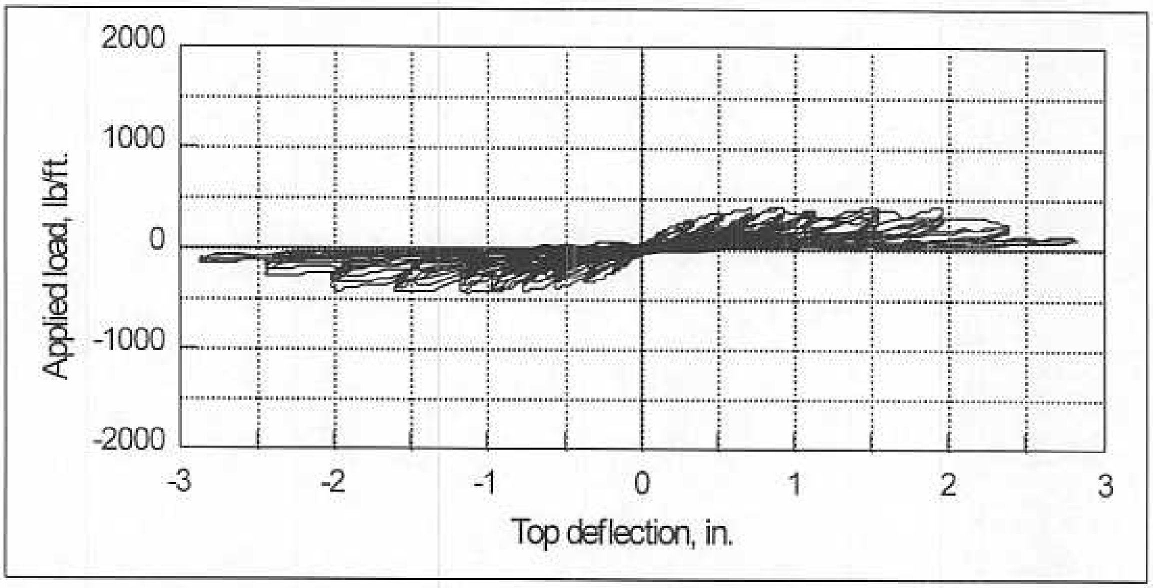


Figure B.18. Load vs. top of wall deflection for AISI-D2

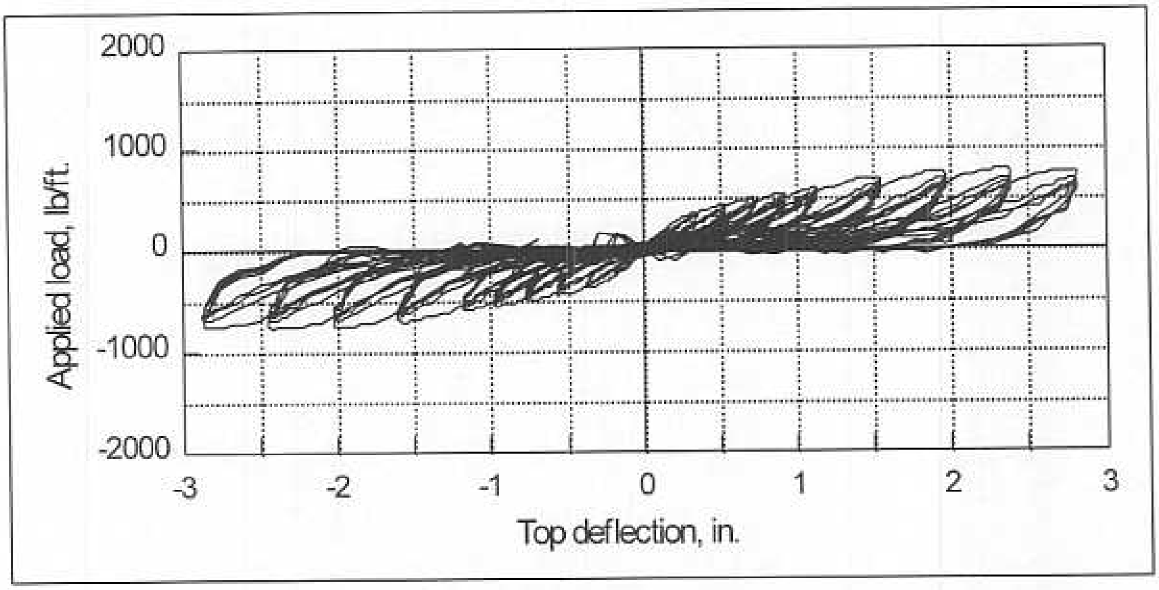


Figure B.19. Load vs. top of wall deflection for AISI-E1

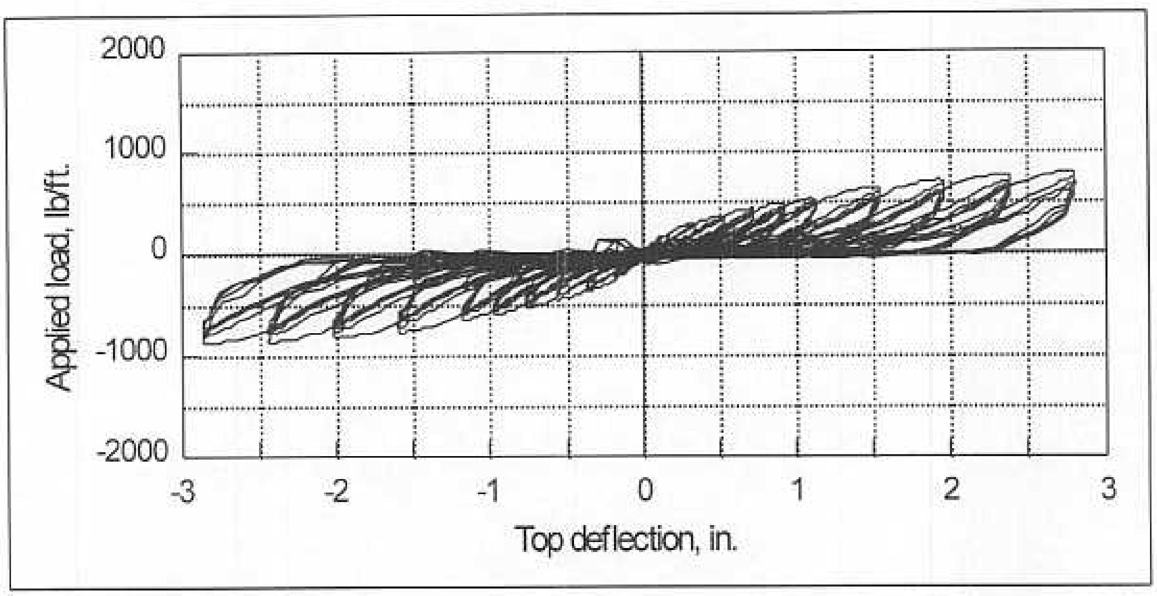


Figure B.20. Load vs. top of wall deflection for AISI-E2

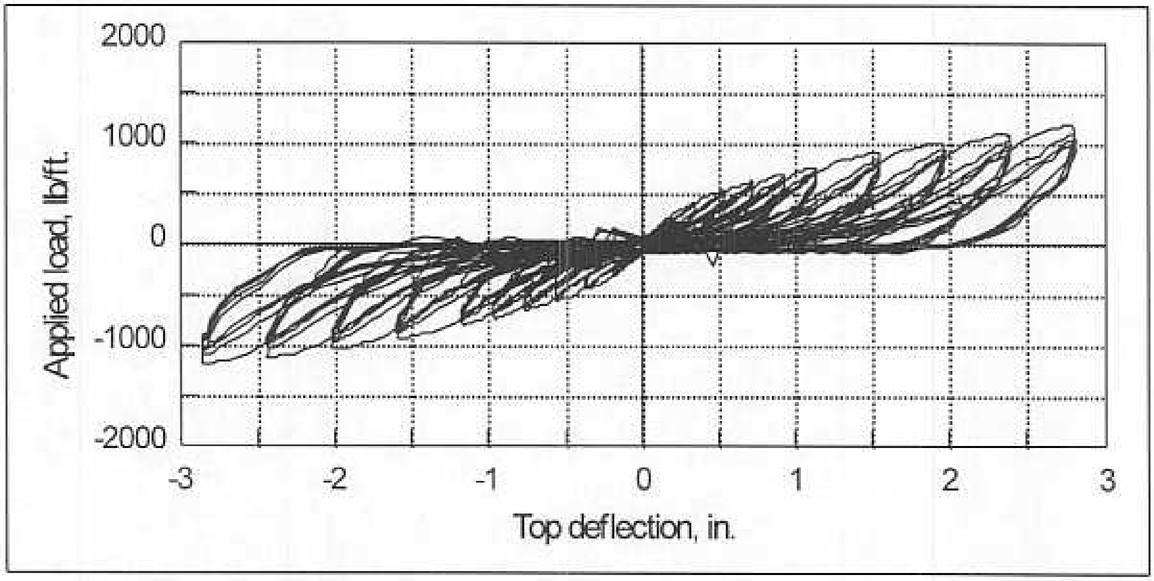


Figure B.21. Load vs. top of wall deflection for AISI-E3

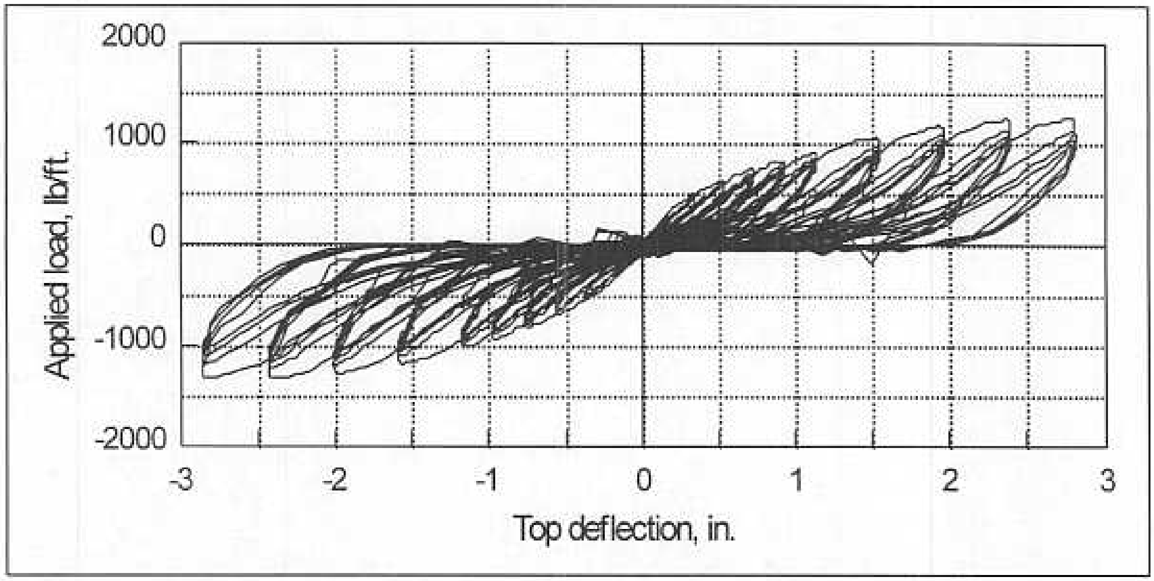


Figure B.22. Load vs. top of wall deflection for AISI-E4

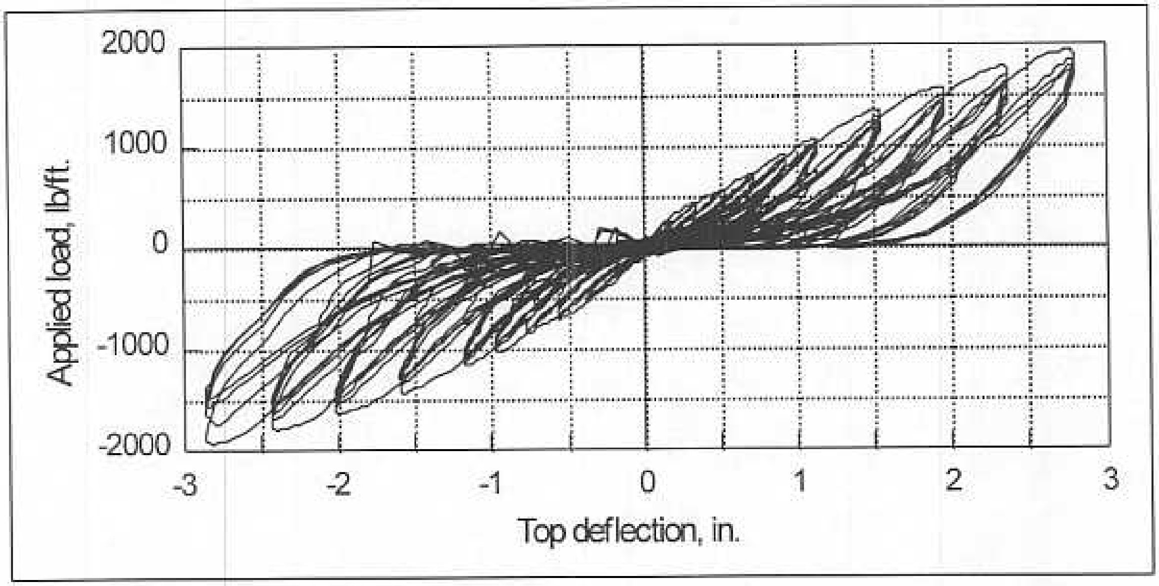


Figure B.23. Load vs. top of wall deflection for AISI-E5

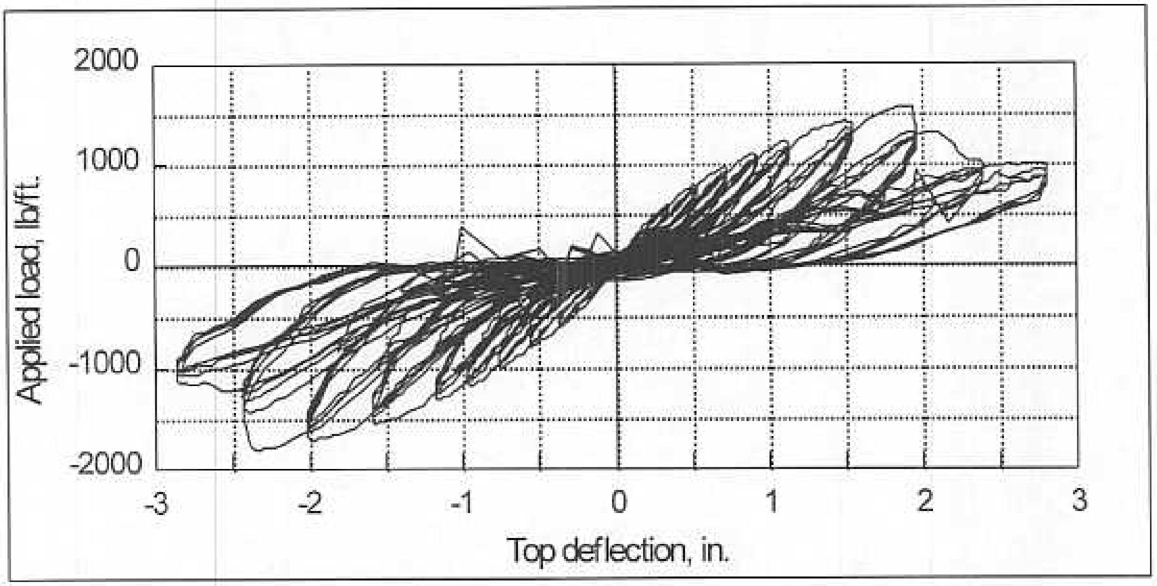


Figure B.24. Load vs. top of wall deflection for AISI-E6

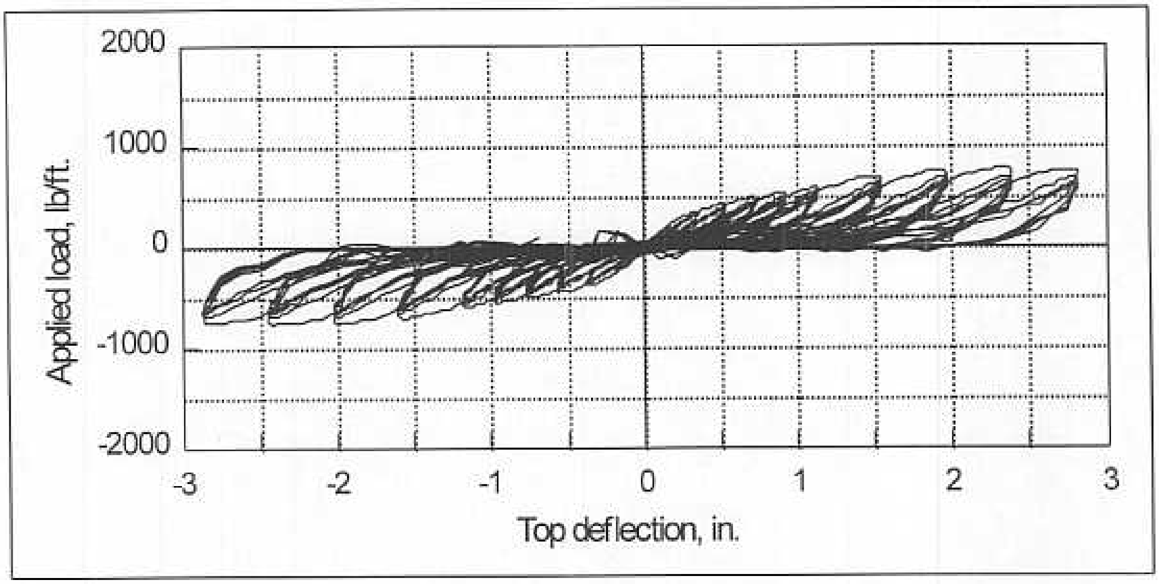


Figure B.19. Load vs. top of wall deflection for AISI-E1

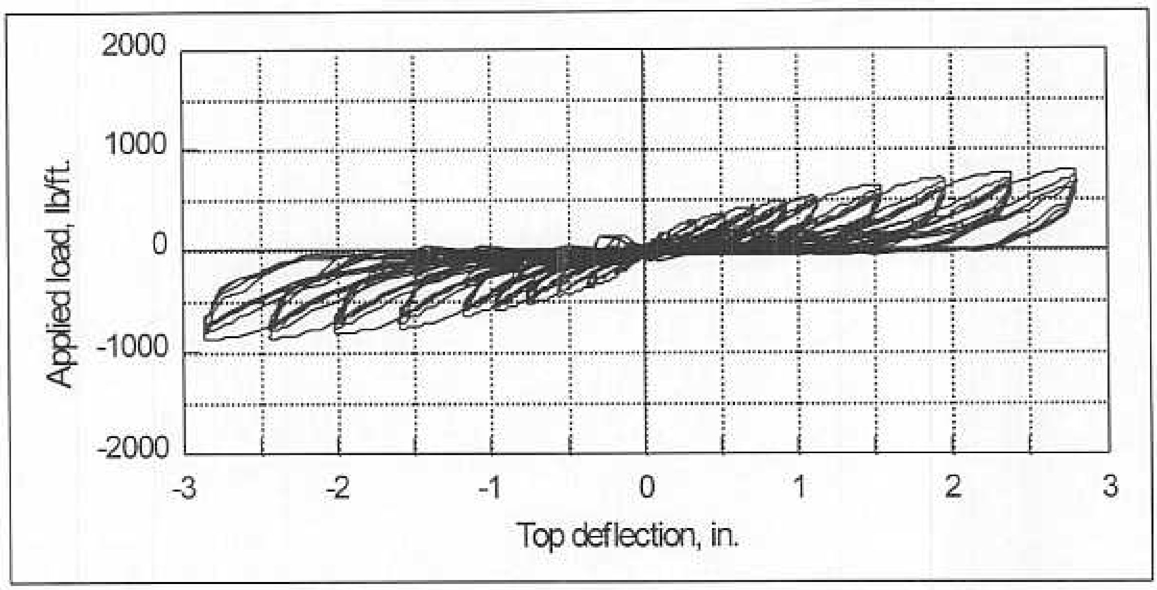


Figure B.20. Load vs. top of wall deflection for AISI-E2

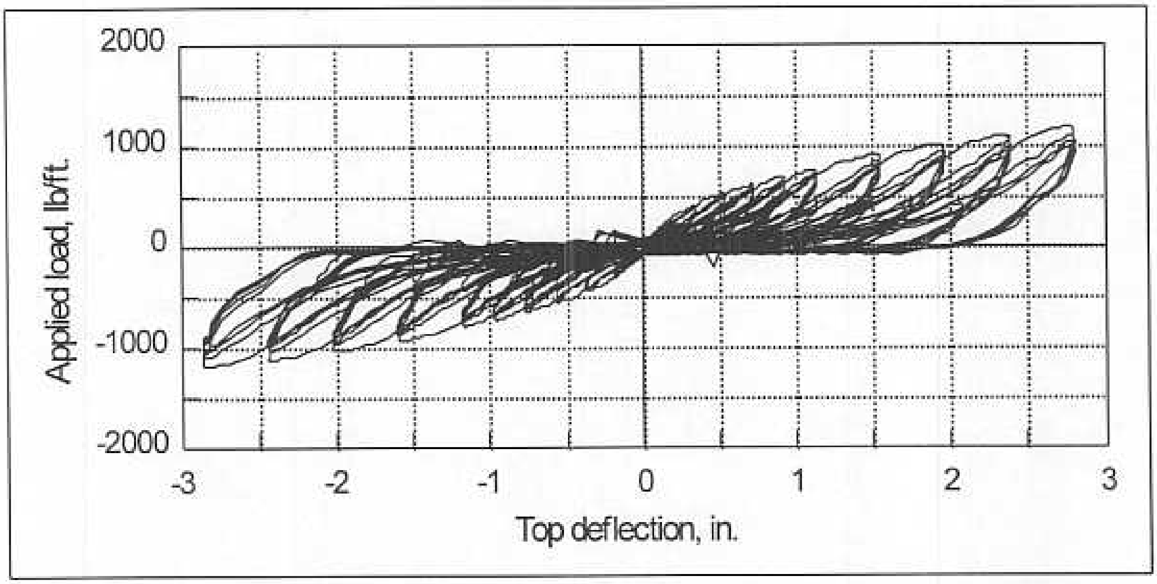


Figure B.21. Load vs. top of wall deflection for AISI-E3

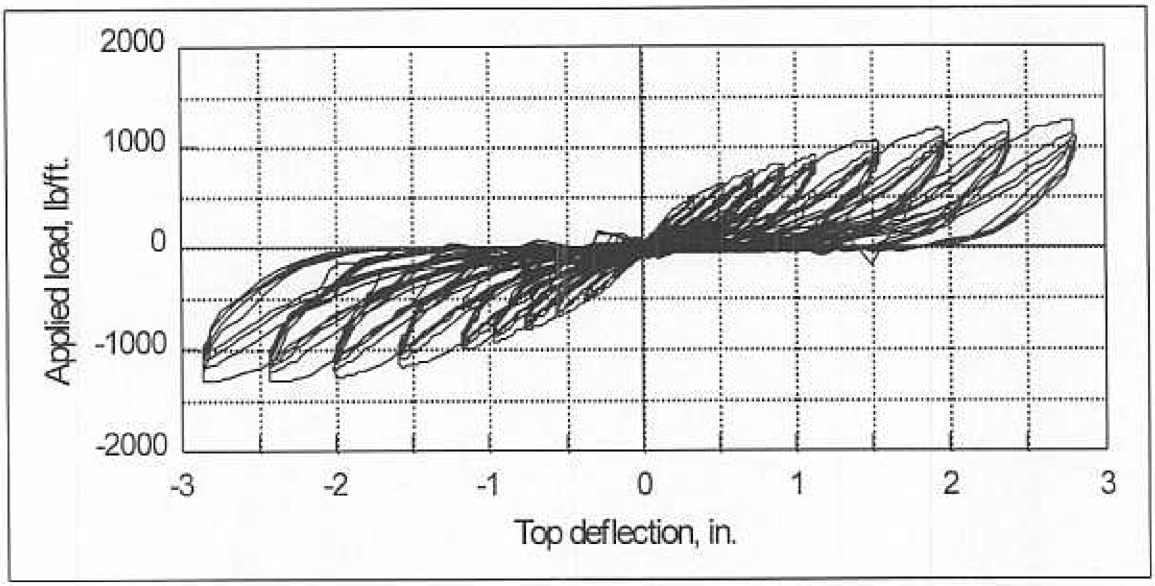


Figure B.22. Load vs. top of wall deflection for AISI-E4

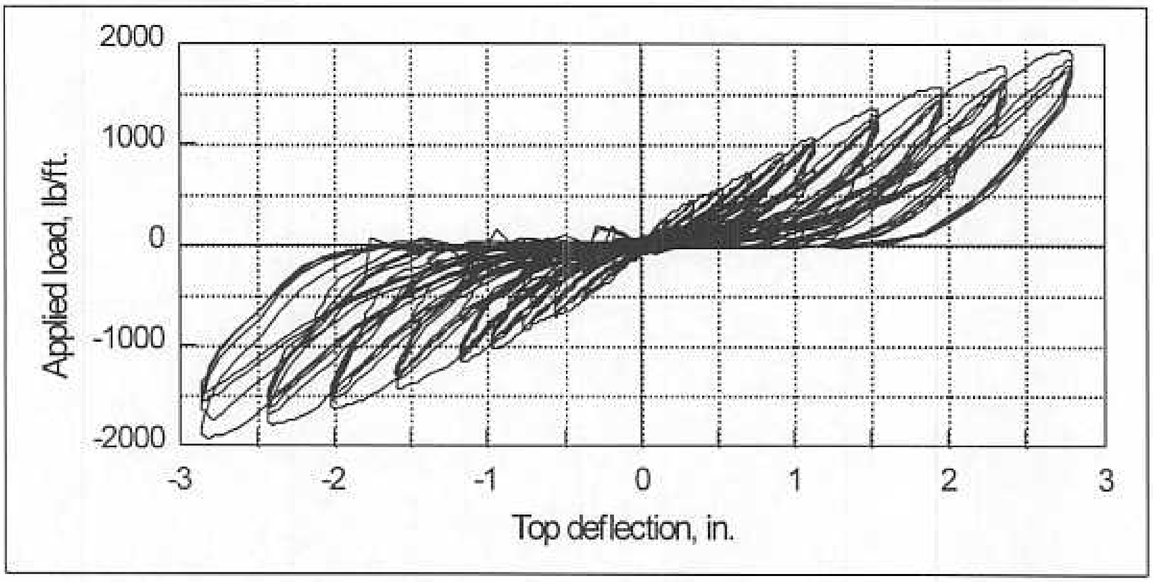


Figure B.23. Load vs. top of wall deflection for AISI-E5

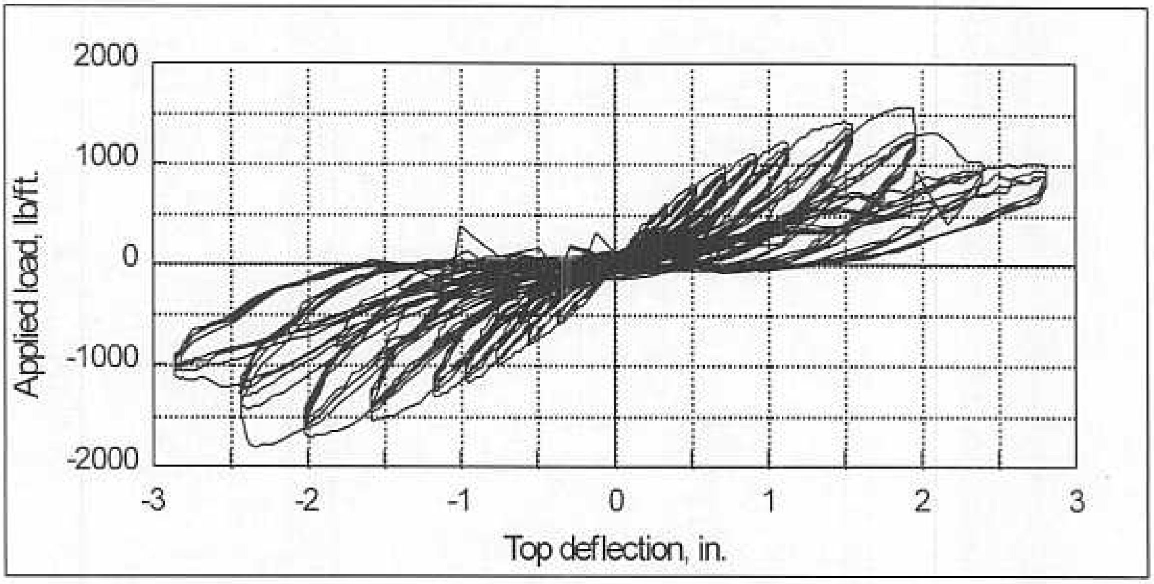


Figure B.24. Load vs. top of wall deflection for AISI-E6

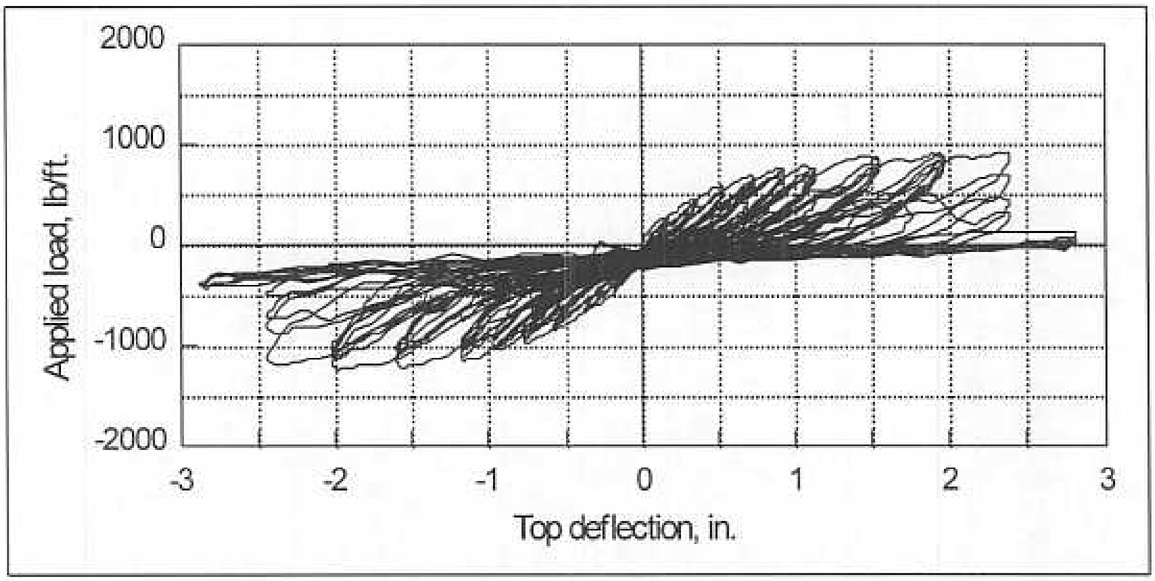


Figure B.25. Load vs. top of wall deflection for AISI-F1

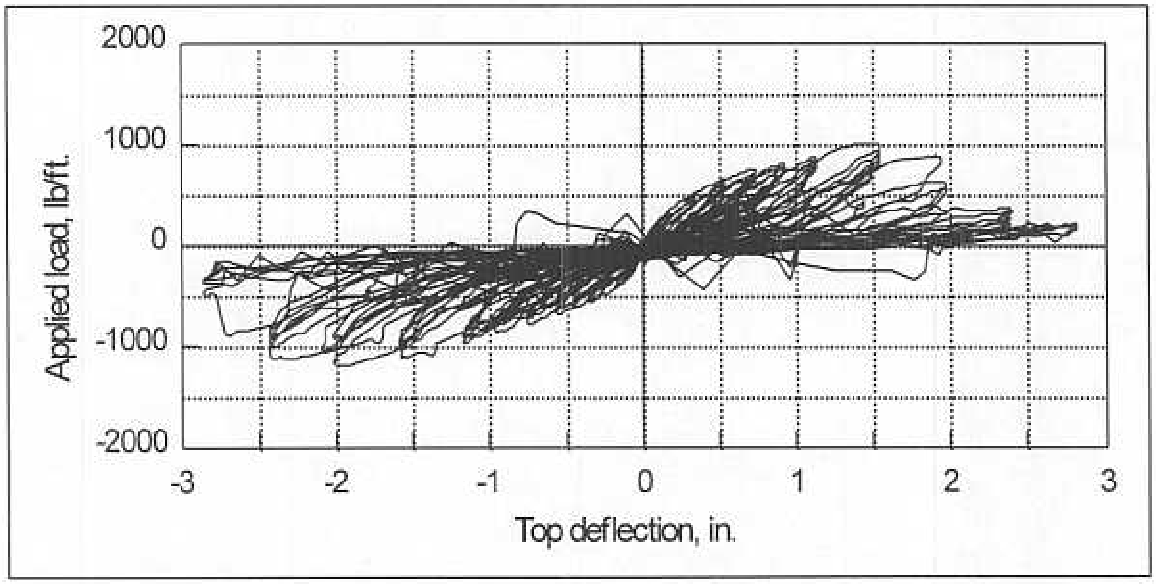


Figure B.26. Load vs. top of wall deflection for AISI-F2

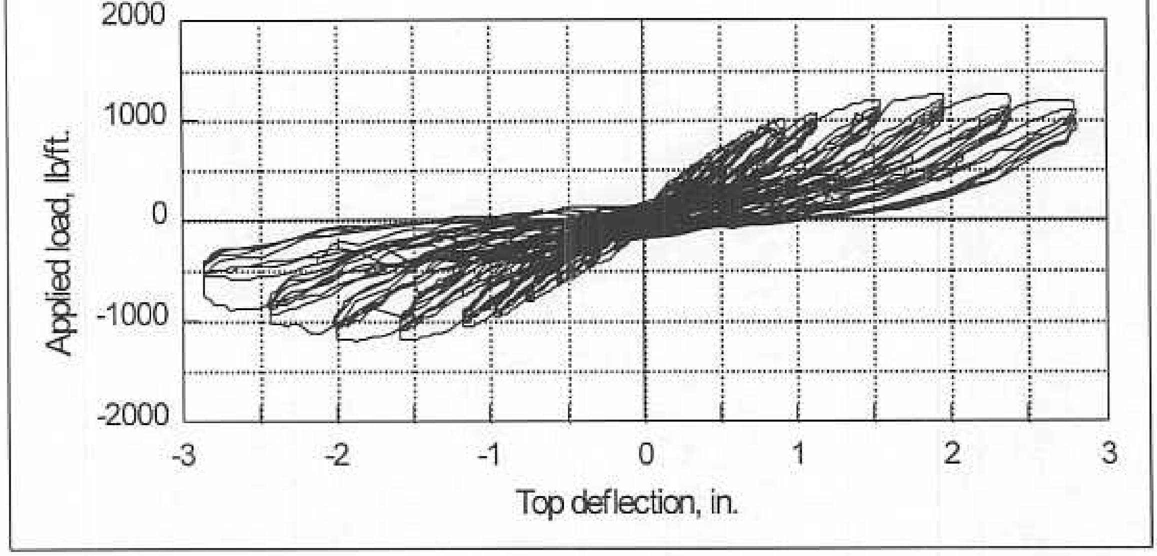


Figure B.27. Load vs. top of wall deflection for AISI-F3

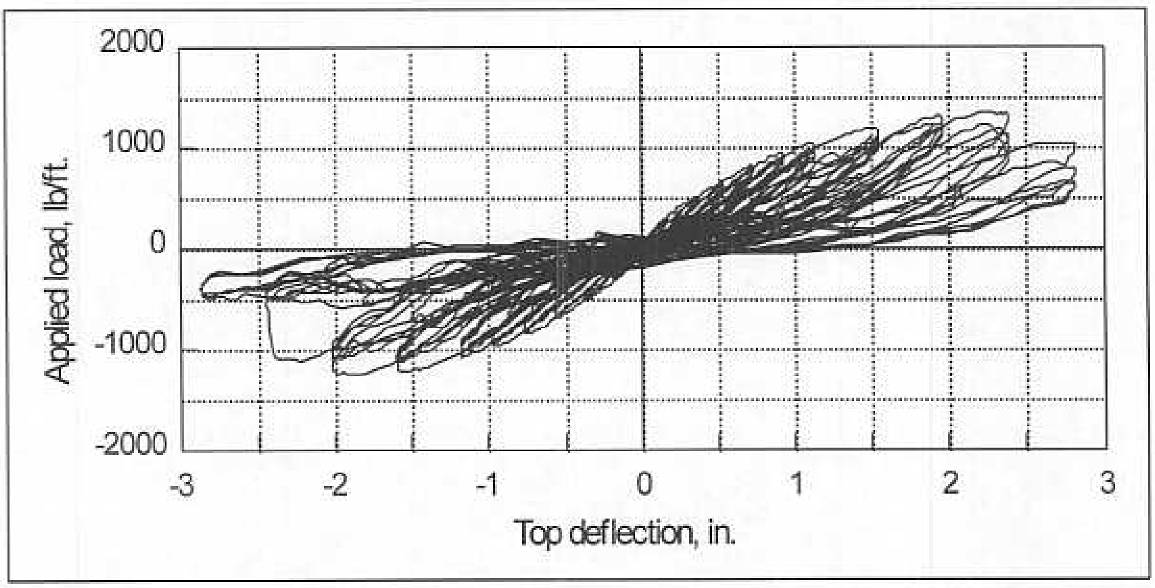
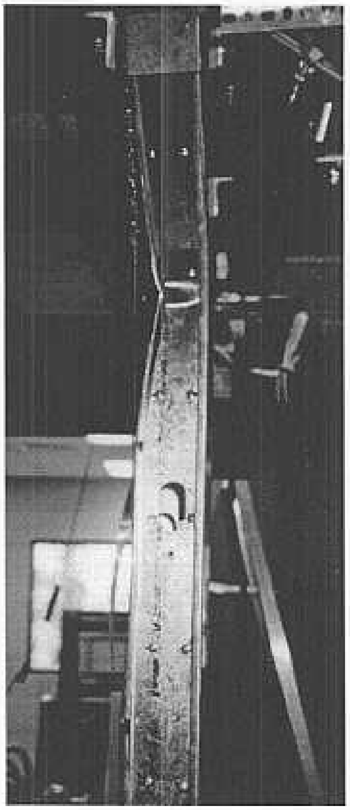


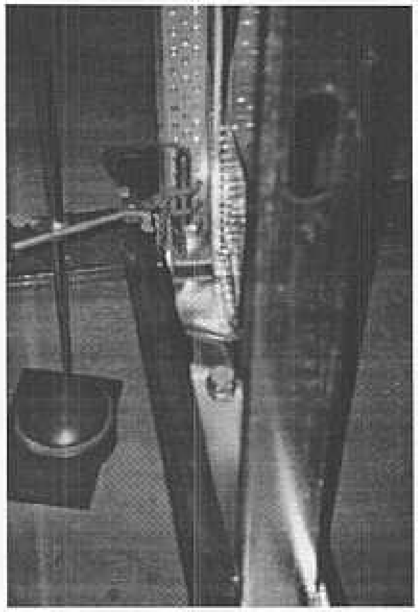
Figure B.28. Load vs. top of wall deflection for AISI-F4

APPENDIX C:

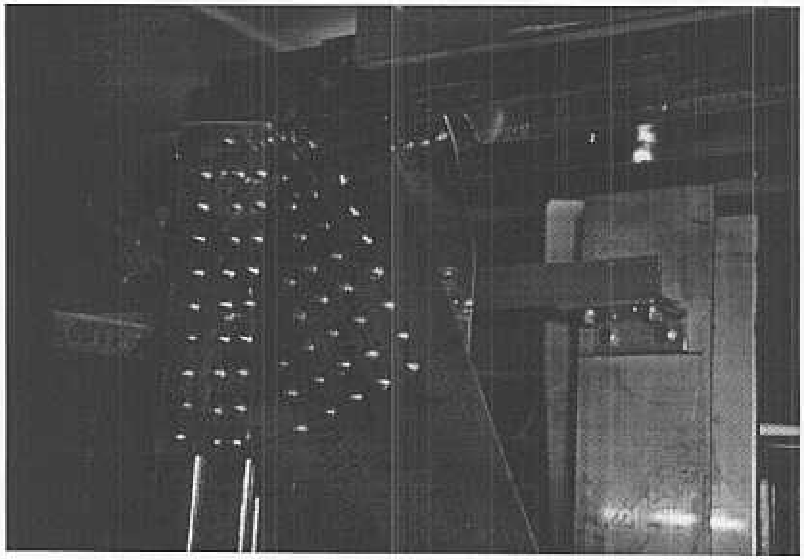
Modes of Failure--Static Tests



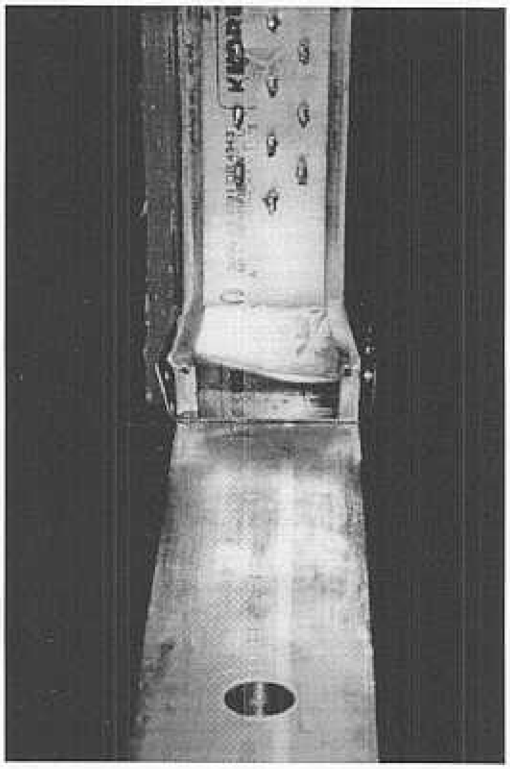
AISI-2



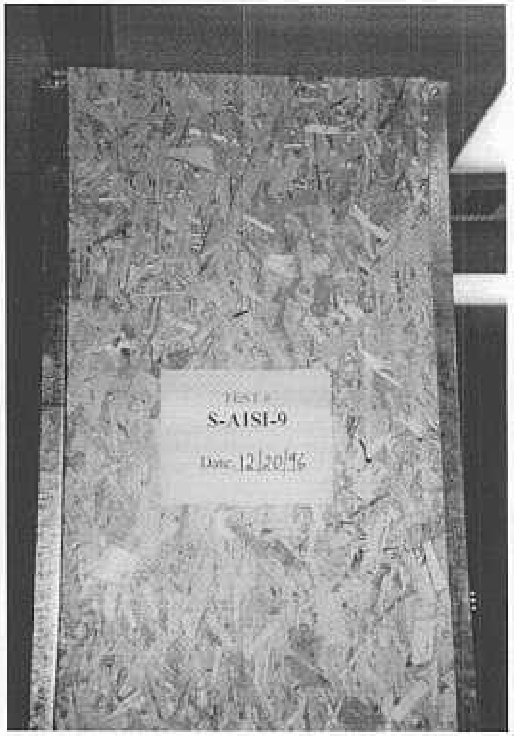
AISI-3



AISI-4



AISI-8

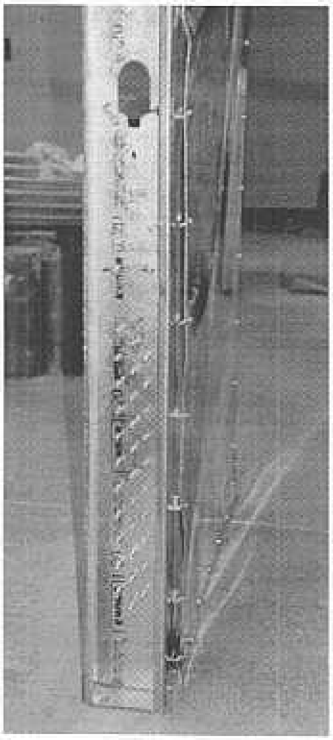


AISI-9

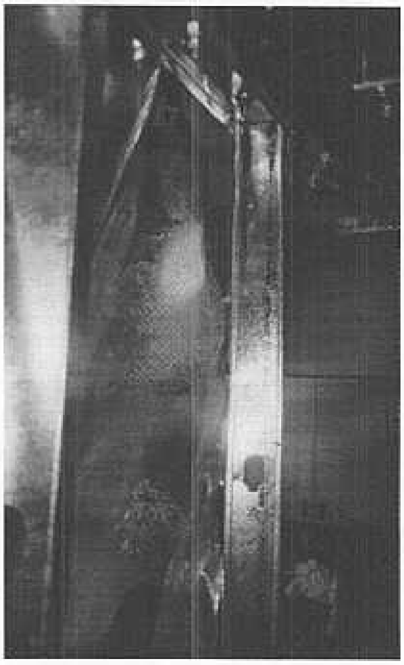
AISI-10

AISI-11

AISI-13



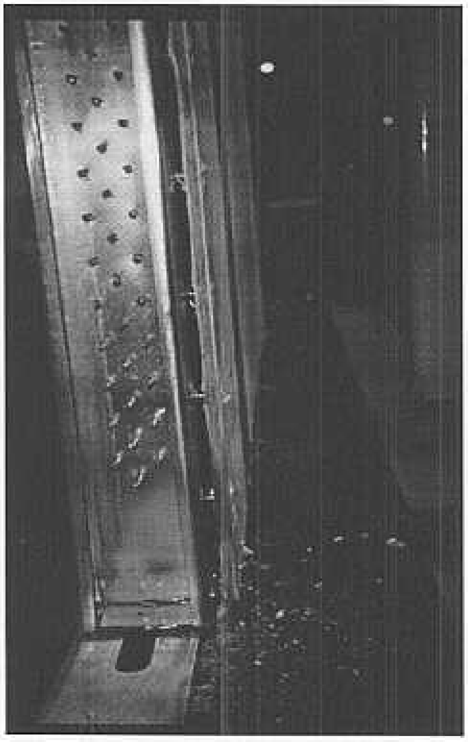
AISI-14



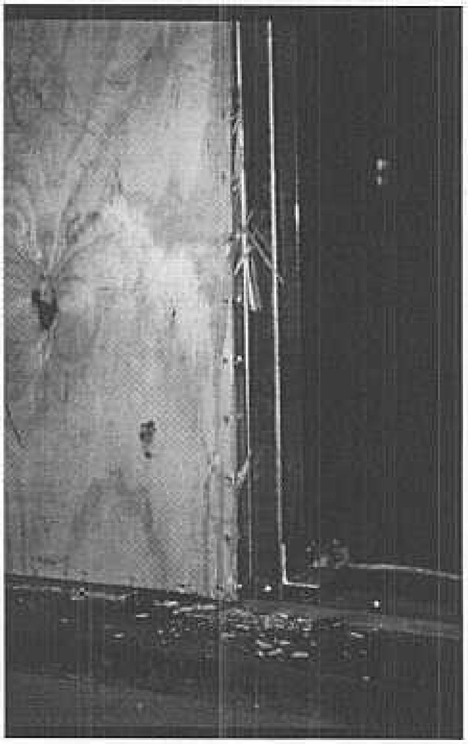
AISI-15

APPENDIX D:

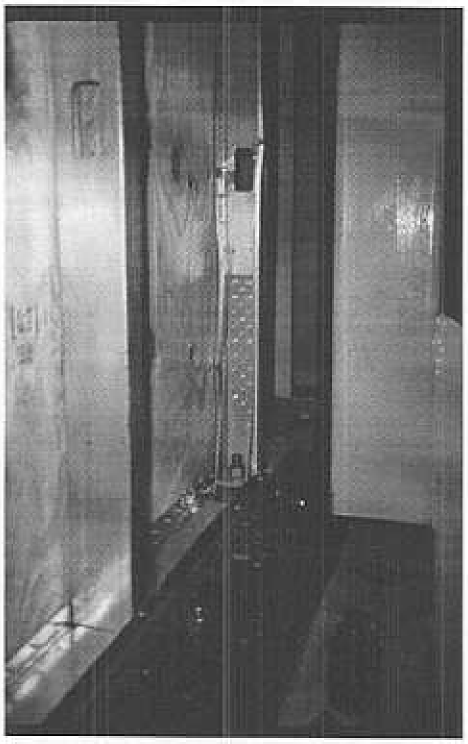
Modes of Failure--Cyclic Tests



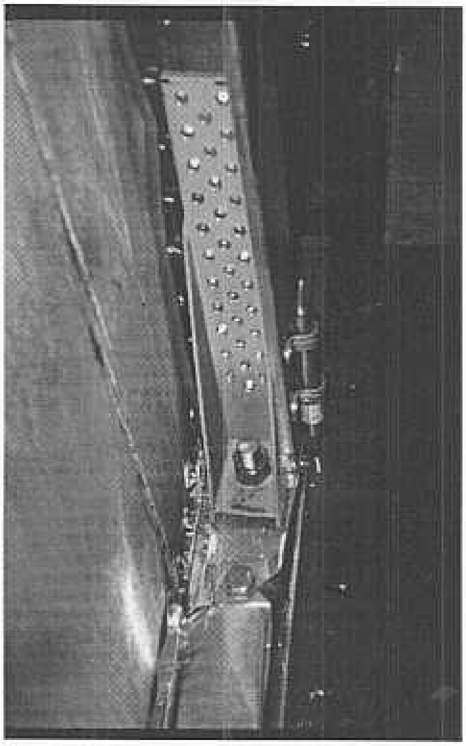
AISI-A1



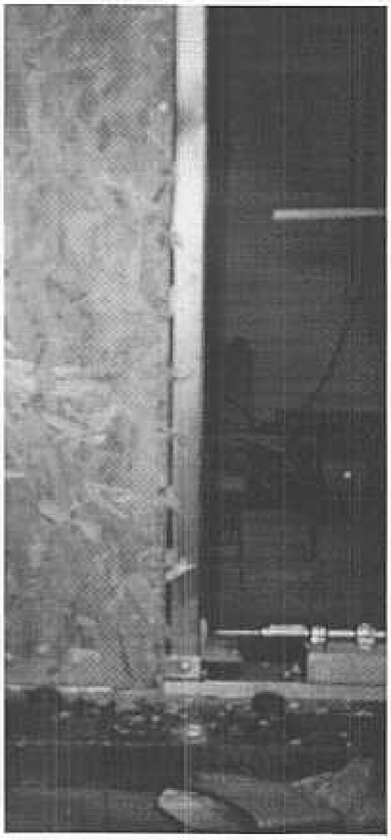
AISI-A2



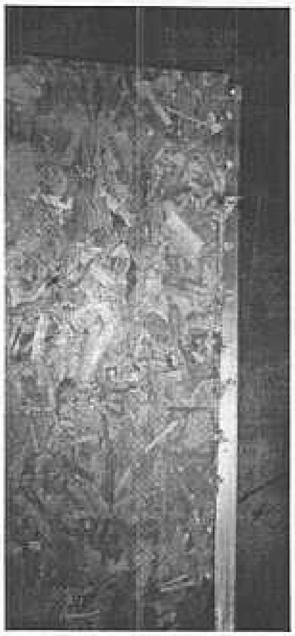
AISI-A3



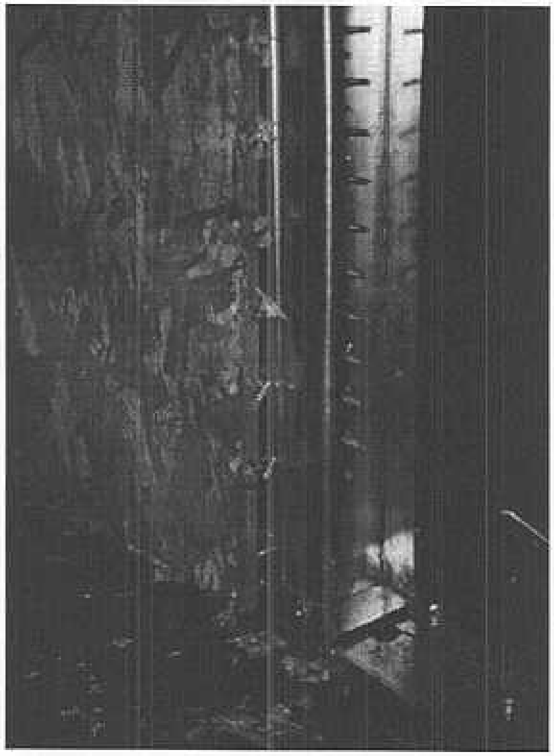
AISI- A4



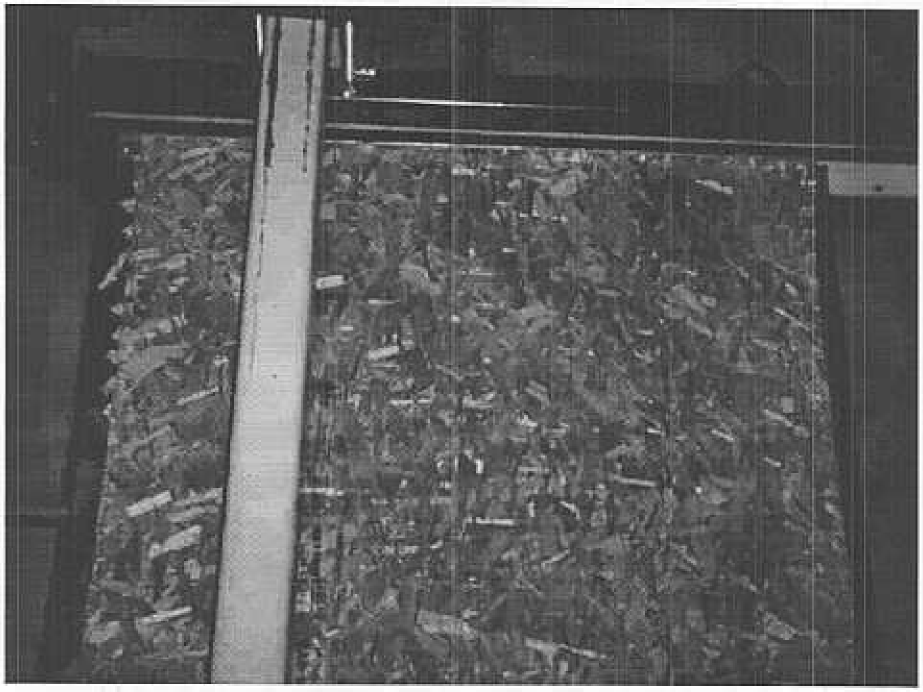
AISI-A5



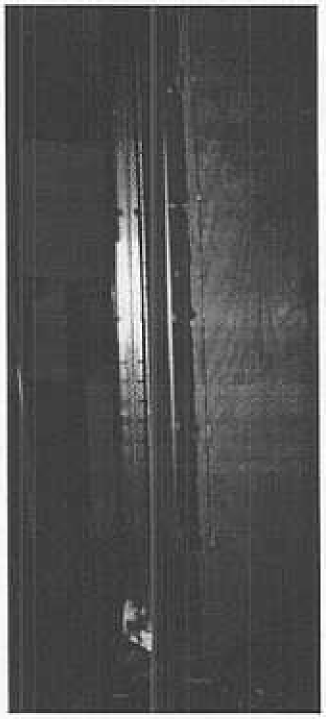
AISI-A6



AISI-A7



AISI-A8



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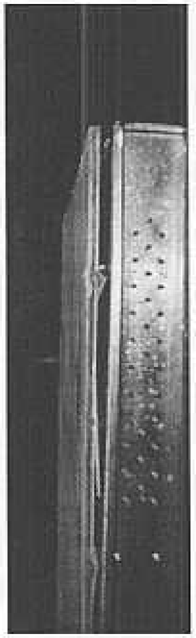

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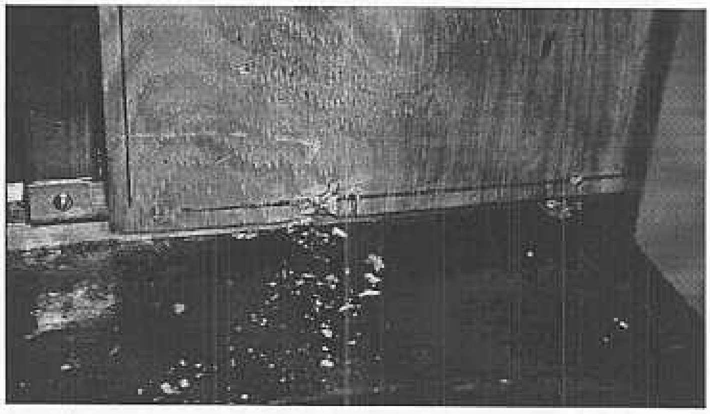

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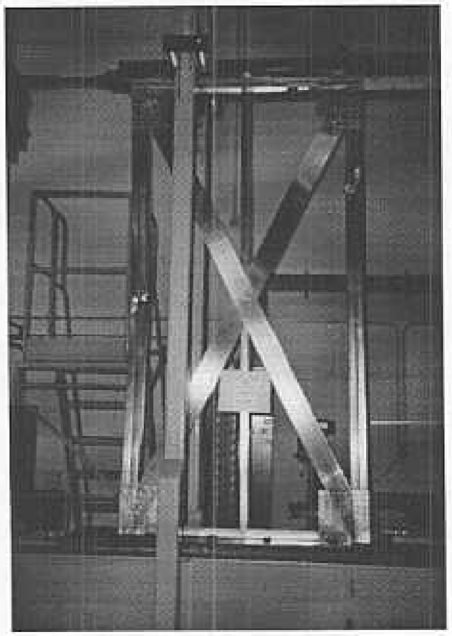

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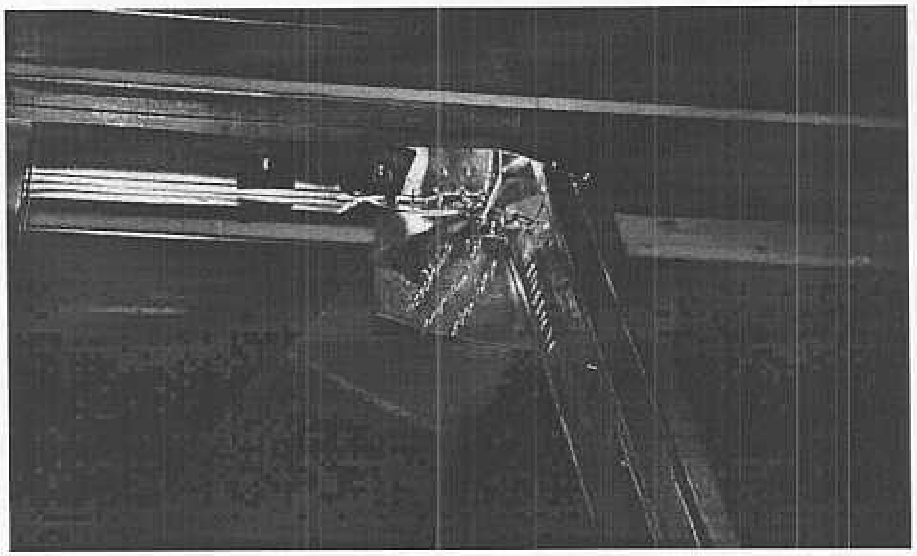

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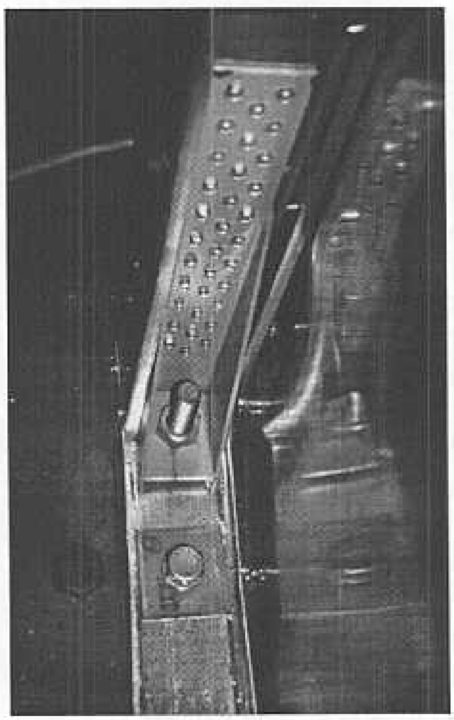

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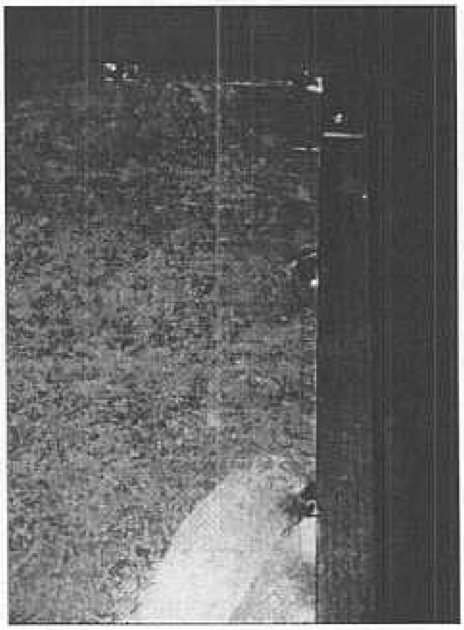

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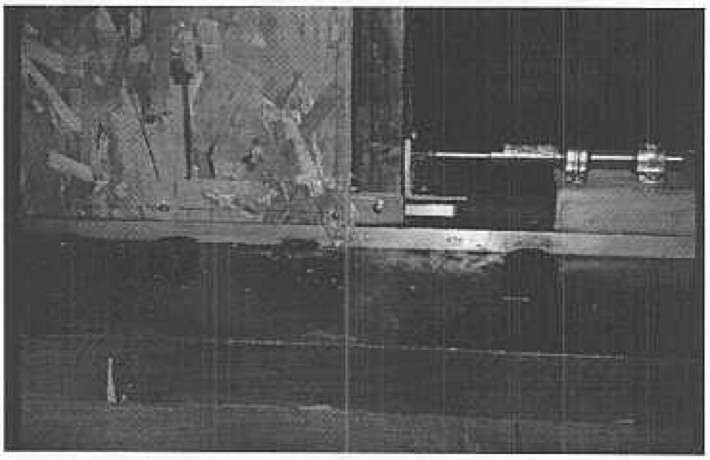

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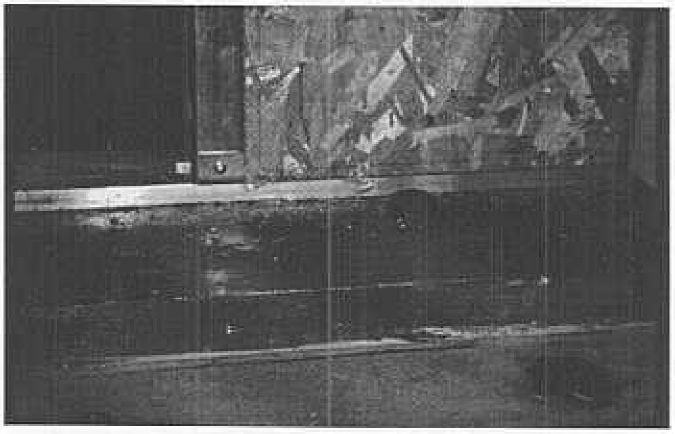

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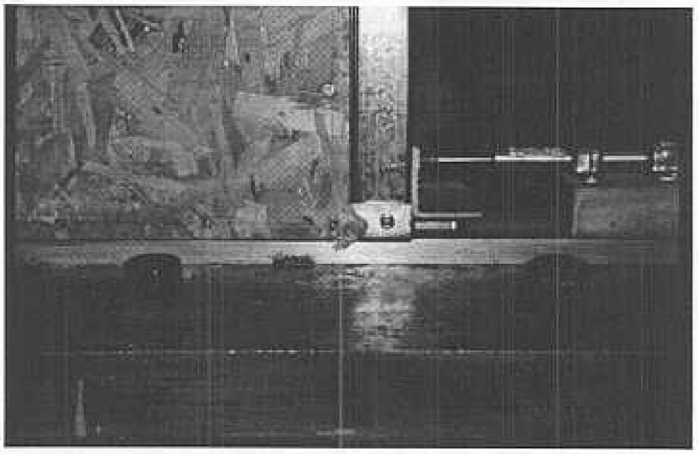

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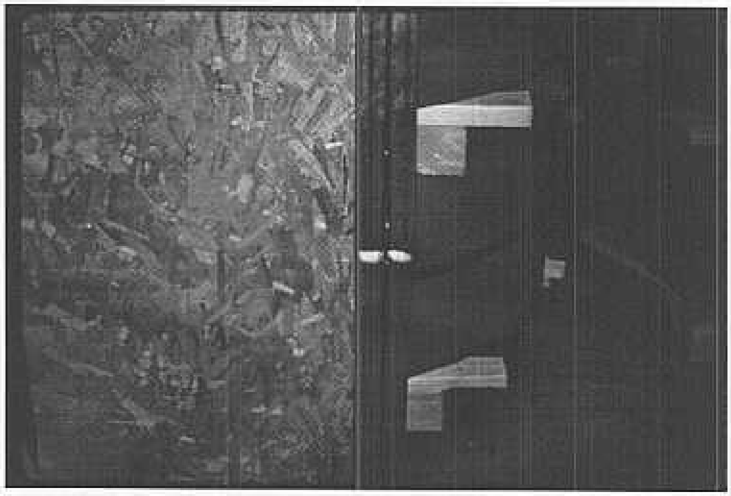

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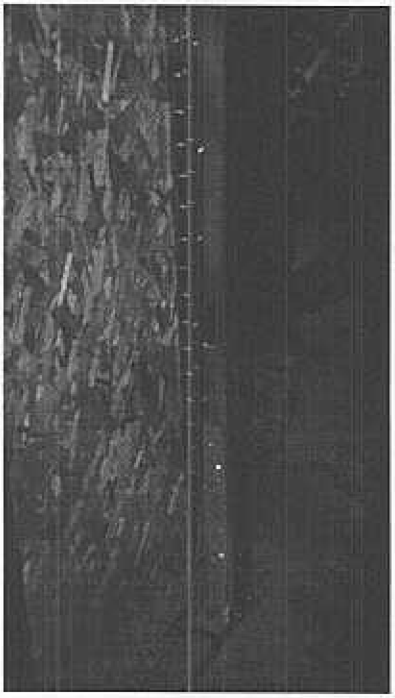

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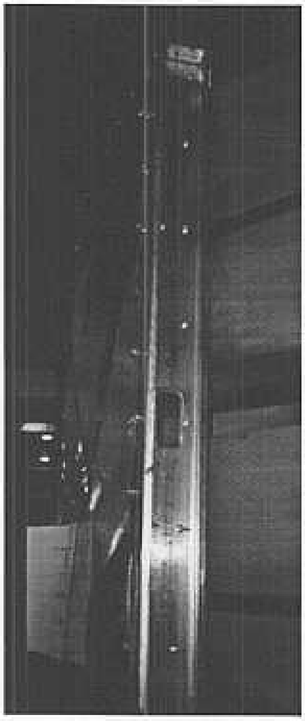

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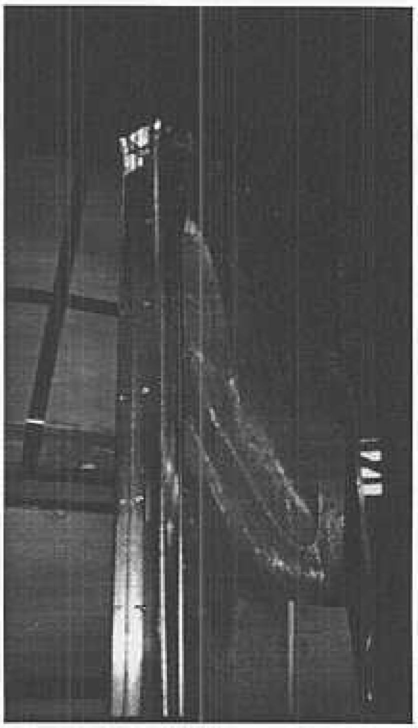

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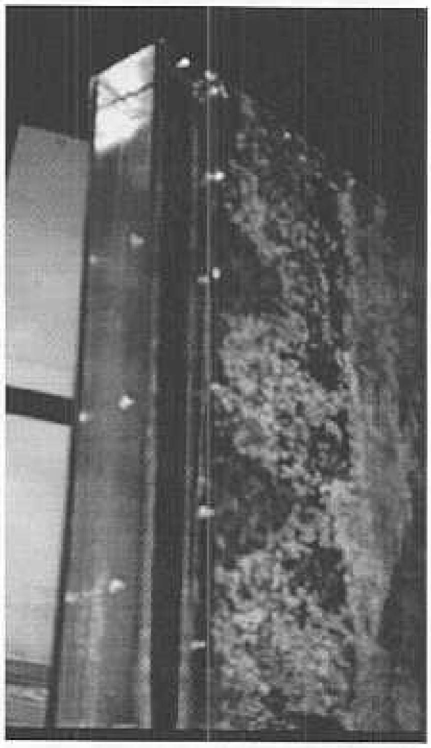

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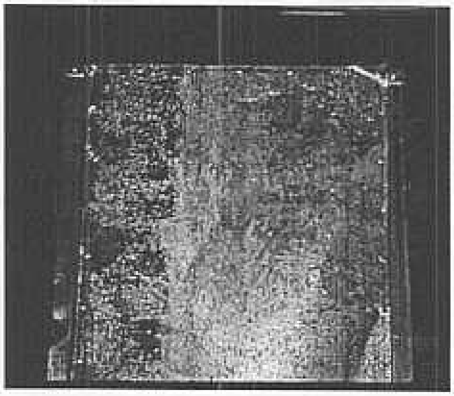

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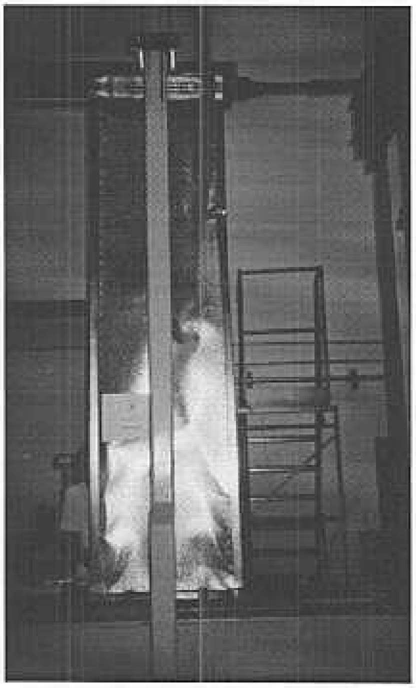

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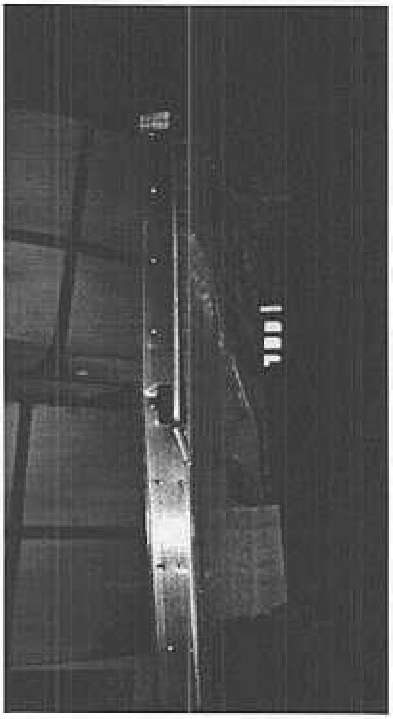

AISI-F4b

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