Memorandum

U.S. Department
of Transportation

Federal Highway
Administration

Date JUL 1 1996

Subject **ACTION**: Wyoming Bridge Railings

Reply to
Attn of HNG-14

From Acting Chief, Federal-Aid and Design
Division

To Mr. Vincent F. Schimmoller
Regional Administrator (HES-08)
Lakewood, Colorado

Your May 30 office memorandum to Mr. Gerald L. Eller requested our review and acceptance of a National Cooperative Highway Research Program (NCHRP) Report 350 test level 4 (TL-4) bridge railing developed by the Wyoming Department of Transportation (WYDOT). This railing was tested by the Texas Transportation Institute (TTI) and documented in its January 1996 report entitled "Wyoming Test Level 4 Bridge Railing." Subsequently, a memorandum dated June 6 was sent to Mr. Seppo Sillan from our Wyoming Division Administrator requesting our acceptance of WYDOT's current bridge railing design as a TL-3 bridge rail. This request included a test report also prepared by TTI, dated May 1996 and entitled "Testing and Evaluation of the Wyoming 740WYBRAIL Bridge Railing System."

After reviewing the reports and the crash videos, we agree that the first design, the WYDOT TL-4 Bridge Railing shown in Enclosure 1, meets all the NCHRP Report 350 acceptance criteria for a TL-4 longitudinal barrier. Enclosure 2 contains a summary of the results from the three NCHRP Report 350 tests that were run on this design, i.e., test nos. 4-10, 4-11, and 4-12.

The second railing, the Wyoming 2-tube, curb-mounted design, was previously accepted under the NCHRP Report 230 criteria. This design, shown in Enclosure 3, has now been tested successfully with the 2000-kg pickup truck, thus qualifying it as an NCHRP Report 350 TL-3 railing. Enclosure 4 summarizes the test results.

Although all of the test results were successful, we believe that two of the design details for these railings could result in vehicular snagging under some impact conditions. One of these details is the flat steel plate welded to the terminal sections of both designs. A vehicle hitting the rail on the departure end of a bridge might snag on the edge of this plate. Lengthening and bending this plate away from the face of the rail elements would eliminate this potential problem. The second detail is somewhat similar but is probably less critical. This is the brace bar that is welded between the two rails to support the terminal section during shipping. Although recessed approximately 50 mm from the face of the rails, it too could present a snag point under some impact conditions. Use of a temporary support brace or increasing the offset distance of a permanent brace to match the face of rail to support post offset distance might be considered to address this concern.

There have been concerns in the past that some steel tube sections can shatter upon impact at extremely low temperatures. Since the materials sent to us for review did not include the specifications for the steel bridge railing tubes, we ask that you provide assurance that WYDOT's specifications address this issue satisfactorily. Enclosures 5 and 6 are excerpts from the AASHTO-AGC-ARTBA June 1979 "Guide for Standardized Highway Barrier Rail Hardware" and the 1995 "Guide to Standardized Highway Barrier Hardware", respectively, which address the issue of brittle fracture and suggest additions to the appropriate specifications when A500 steel is used to form the rail elements. Note that Enclosure 5 calls for a modification of the drop-weight tear test, ASTM E436. This modification is based on a New York specification, which was developed to allow testing steel tubes with sides too small to produce specimens of the size required by E436.

By a copy of this memorandum, we will advise the Federal Highway Administration field offices of our action. Unless advised otherwise, we will assume that these railings are non-proprietary and that other highway agencies interested in either of them may contact WYDOT directly to obtain a complete set of drawings.

Seppo I. Sillan

6 Enclosures

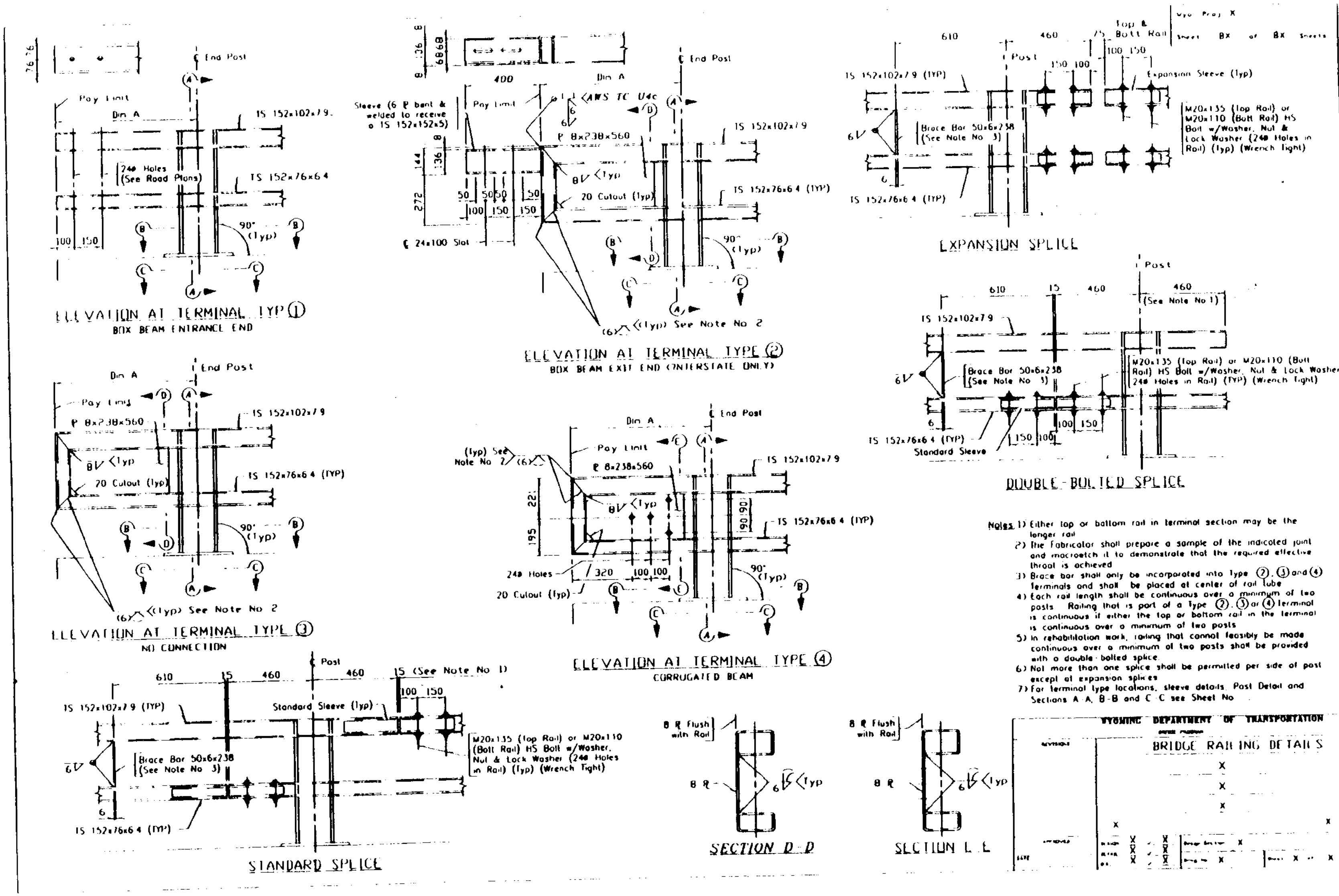


Figure 1. Details of Wyoming TL-4 bridge railing design.

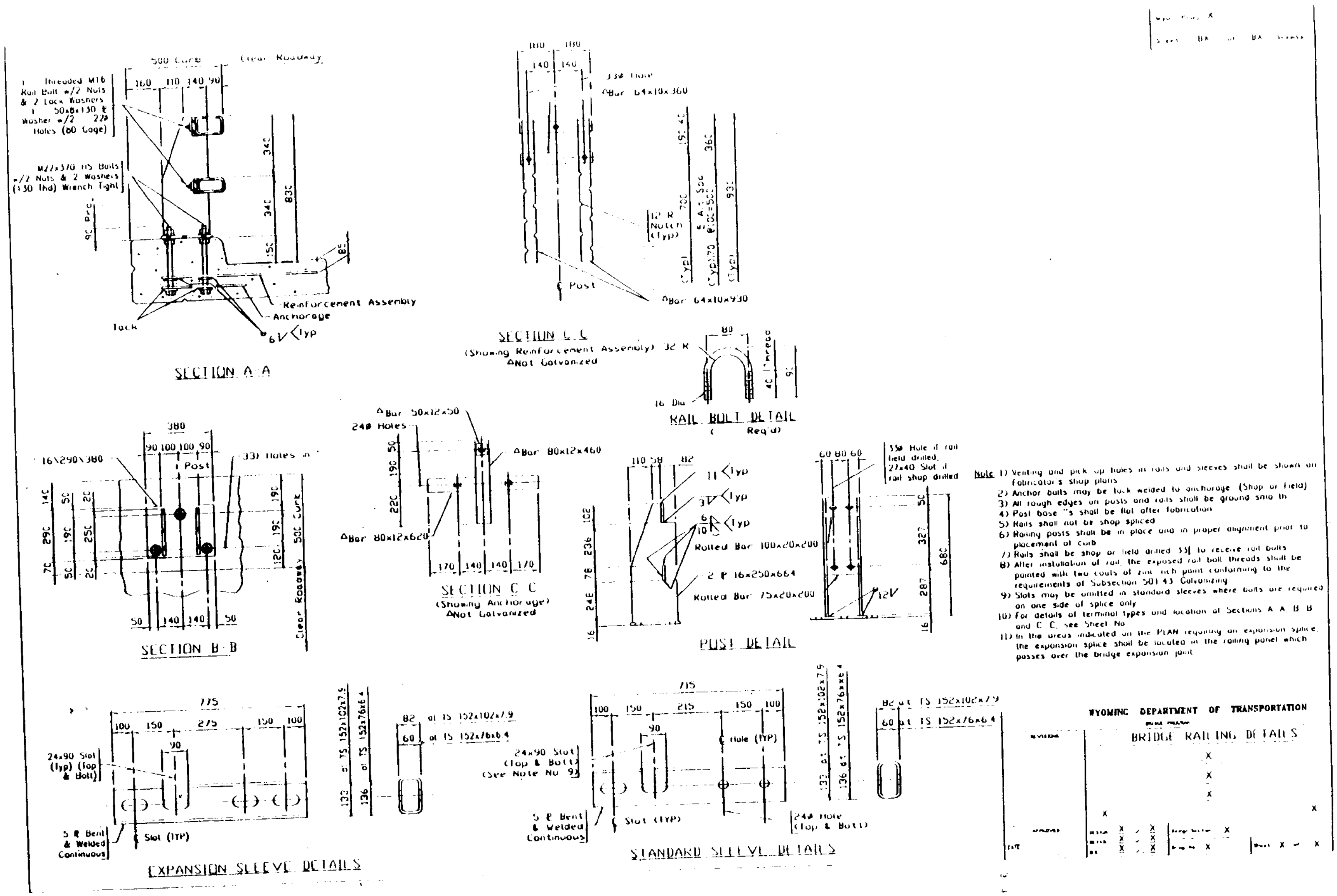
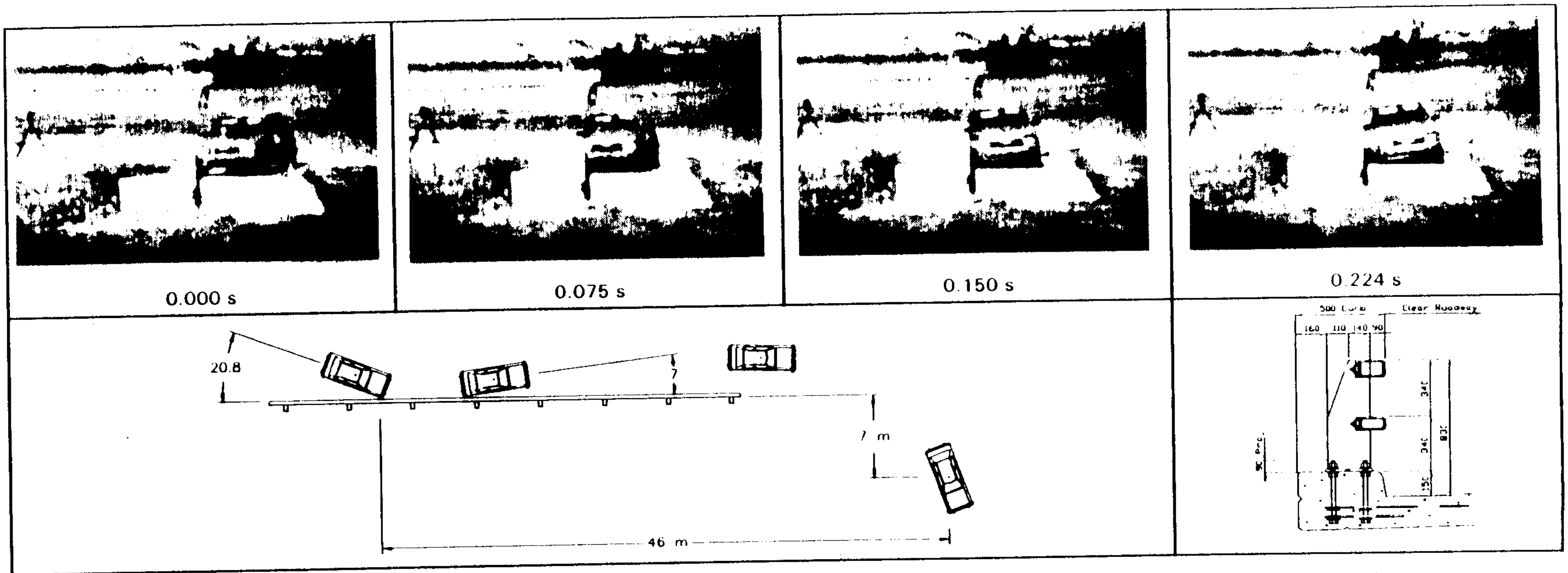


Figure 2. Details of Wyoming bridge deck and curb section.



General Information

Test Agency	Texas Transportation Institute
Test No.	472610-1
Date	10/02/95

Test Article

Type	Bridge Railing
Name	Wyoming TL4 Bridge Railing
Installation Length (m)	23
Size and/or dimension and material of key elements	Tubular steel railing on concrete bridge deck and curb
Soil Type and Condition	Concrete bridge deck, dry

Test Vehicle

Type	Production
Designation	820C
Model	1988 Ford Festiva
Mass (kg) Curb	785
Test Inertial	820
Dummy	76
Gross Static	896

Impact Conditions

Speed (km/h)	97.8
Angle (deg)	20.8

Exit Conditions

Speed (km/h)	48.8
Angle (deg)	7.0

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	5.5
y-direction	5.8
THIV (optional)	
Ridedown Accelerations (g's)	
x-direction	-4.0
y-direction	-3.4
PHD (optional)	
ASI (optional)	
Max. 0.050-sec Average (g's)	
x-direction	-8.5
y-direction	-10.9
z-direction	3.3

Test Article Deflections (m)

Dynamic	nil
Permanent	nil

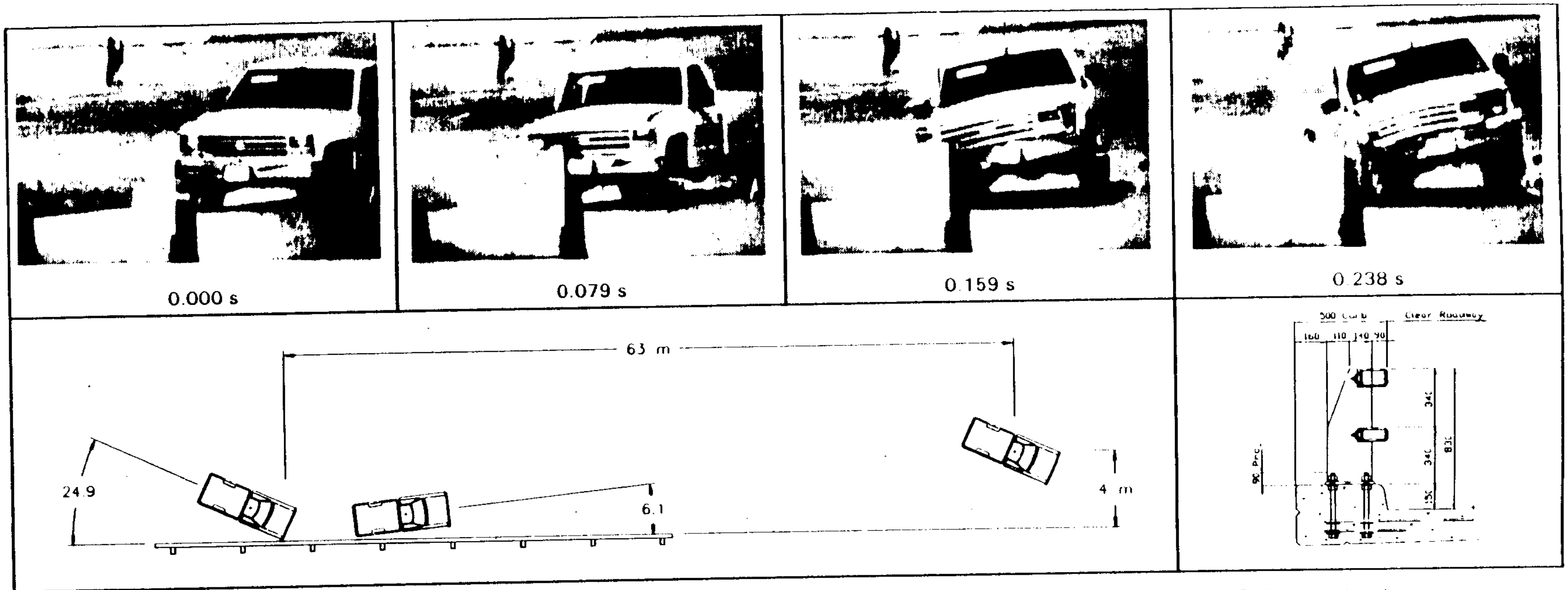
Vehicle Damage

Exterior	
VDS	01RFQ5
CDC	01FREK2 & 01RDES3
Interior	
OCDI	RS0000000
Maximum Exterior Vehicle Crush (mm)	120
Max. Occ. Compart. Deformation (mm)	19

Post-Impact Behavior

Max. Roll Angle (deg)	5.2
Max. Pitch Angle (deg)	3.9
Max. Yaw Angle (deg)	-20.5

Figure 8. Summary of results for test 472610-1.



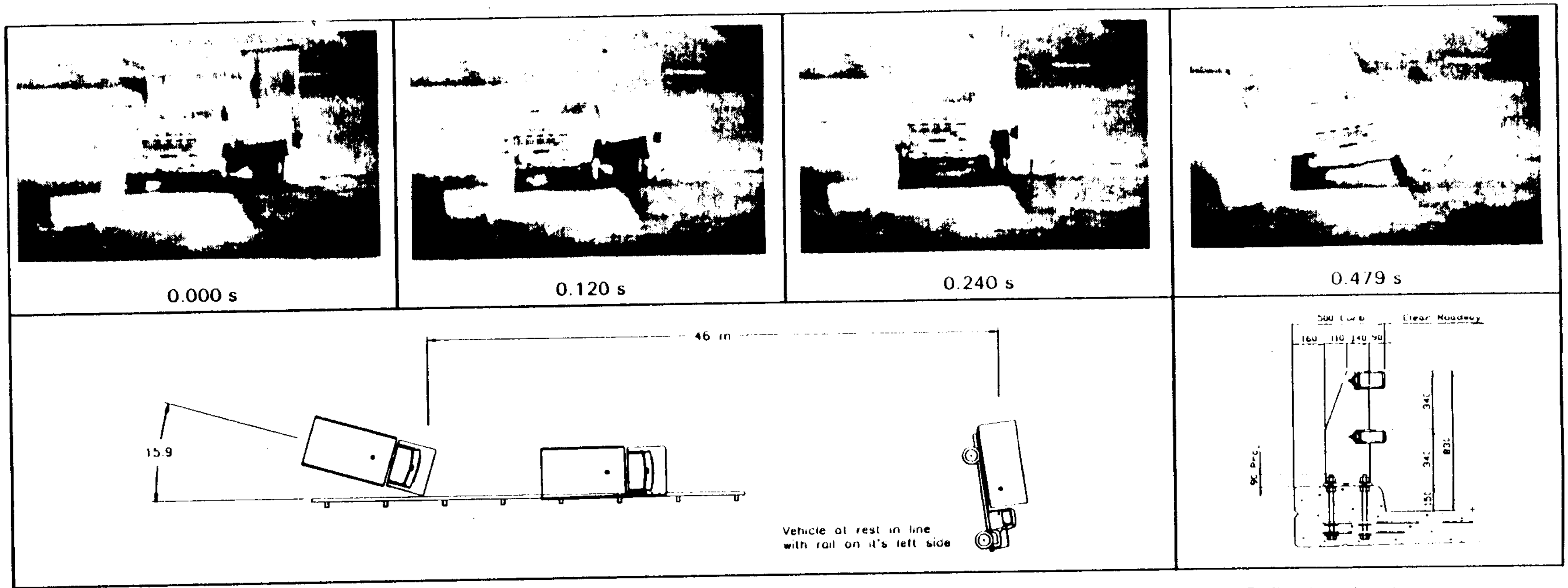
General Information	
Test Agency	Texas Transportation Institute
Test No.	472610-2
Date	10/10/95
Test Article	
Type	Bridge Railing
Name	Wyoming TL4 Bridge Railing
Installation Length (m)	23
Size and/or dimension and material of key elements	Tubular steel railing on concrete deck and curb
Soil Type and Condition	Concrete bridge deck, dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1989 Chevrolet 2500 Pickup
Mass (kg) Curb	1919
Test Inertial	2000
Dummy	No dummy
Gross Static	2000

Impact Conditions	
Speed (km/h)	101.0
Angle (deg)	24.9
Exit Conditions	
Speed (km/h)	85.3
Angle (deg)	6.1
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	6.0
y-direction	6.7
THIV (optional)	
Ridedown Accelerations (g's)	
x-direction	9.2
y-direction	-12.0
PHD (optional)	
ASI (optional)	
Max. 0.050-sec Average (g's)	
x-direction	-10.4
y-direction	-10.4
z direction	-9.4

Test Article Deflections (mm)	
Dynamic	N/A
Permanent	3.2
Vehicle Damage	
Exterior	
VDS	01RFQ4
CDC	01FREK3 &01RDES3
Interior	
OCDI	FS0103000
Maximum Exterior Vehicle Crush (mm)	330
Max. Occ. Compart. Deformation (mm)	79
Post-Impact Behavior	
Max. Roll Angle (deg)	12.6
Max. Pitch Angle (deg)	3.5
Max. Yaw Angle (deg)	36.9

Figure 14. Summary of results for test 472610-2.

(Page 2 of 3)



General Information	
Test Agency	Texas Transportation Institute
Test No.	472610-3
Date	10/12/95
Test Article	
Type	Bridge Railing
Name	Wyoming TL4 Bridge Railing
Installation Length (m)	23
Size and/or dimension and material of key elements	Tubular steel railing on concrete deck and curb
Soil Type and Condition	Concrete bridge deck, dry
Test Vehicle	
Type	Production
Designation	8000S
Model	1980 Ford F700 single-unit truck
Mass (kg) Curb	4653
Test Inertial	8000
Dummy	No dummy
Gross Static	8000

Impact Conditions	
Speed (km/h)	79.7
Angle (deg)	15.9
Exit Conditions	
Speed (km/h)	N/A
Angle (deg)	N/A
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	2.4
y-direction	2.7
THIV (optional)	
Ridedown Accelerations (g's)	
x-direction	-3.5
y-direction	8.7
PHD (optional)	
ASI (optional)	
Max. 0.050-sec Average (g's)	
x-direction	1.5
y-direction	3.9
z-direction	-4.3

Test Article Deflections (mm)	
Dynamic	N/A
Permanent	22
Vehicle Damage	
Exterior	
VDS	N/A
CDC	N/A
Interior	
OCDI	AS0000000
Maximum Exterior Vehicle Crush (mm)	590
Max. Occ. Compart. Deformation (mm)	0
Post-Impact Behavior	
Max. Roll Angle (deg)	7.9
Max. Pitch Angle (deg)	-6.8
Max. Yaw Angle (deg)	17.3

Figure 21. Summary of results for test 472610-3.

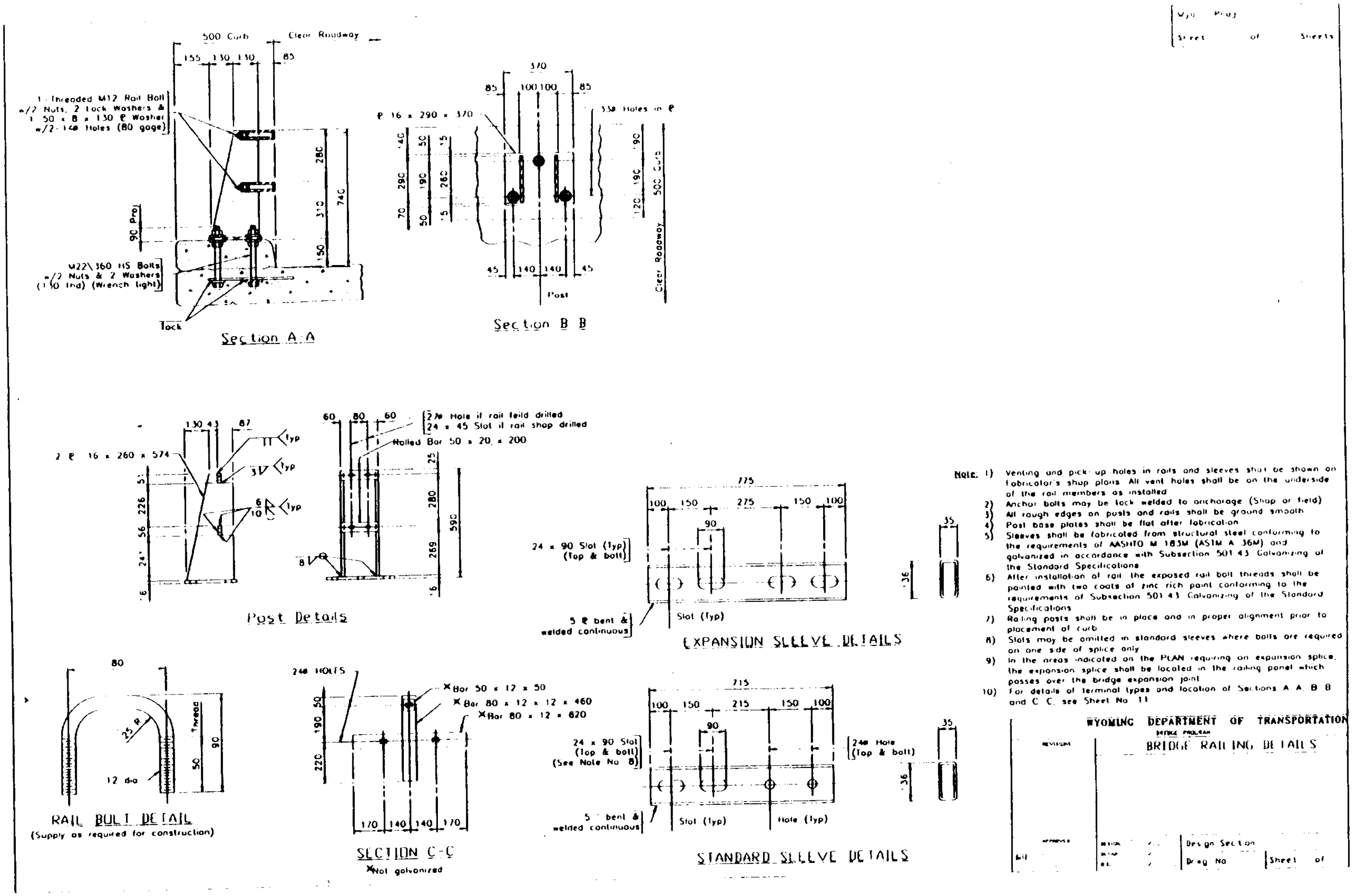


Figure 1. Details of the Wyoming 740WYBRAIL bridge railing design.

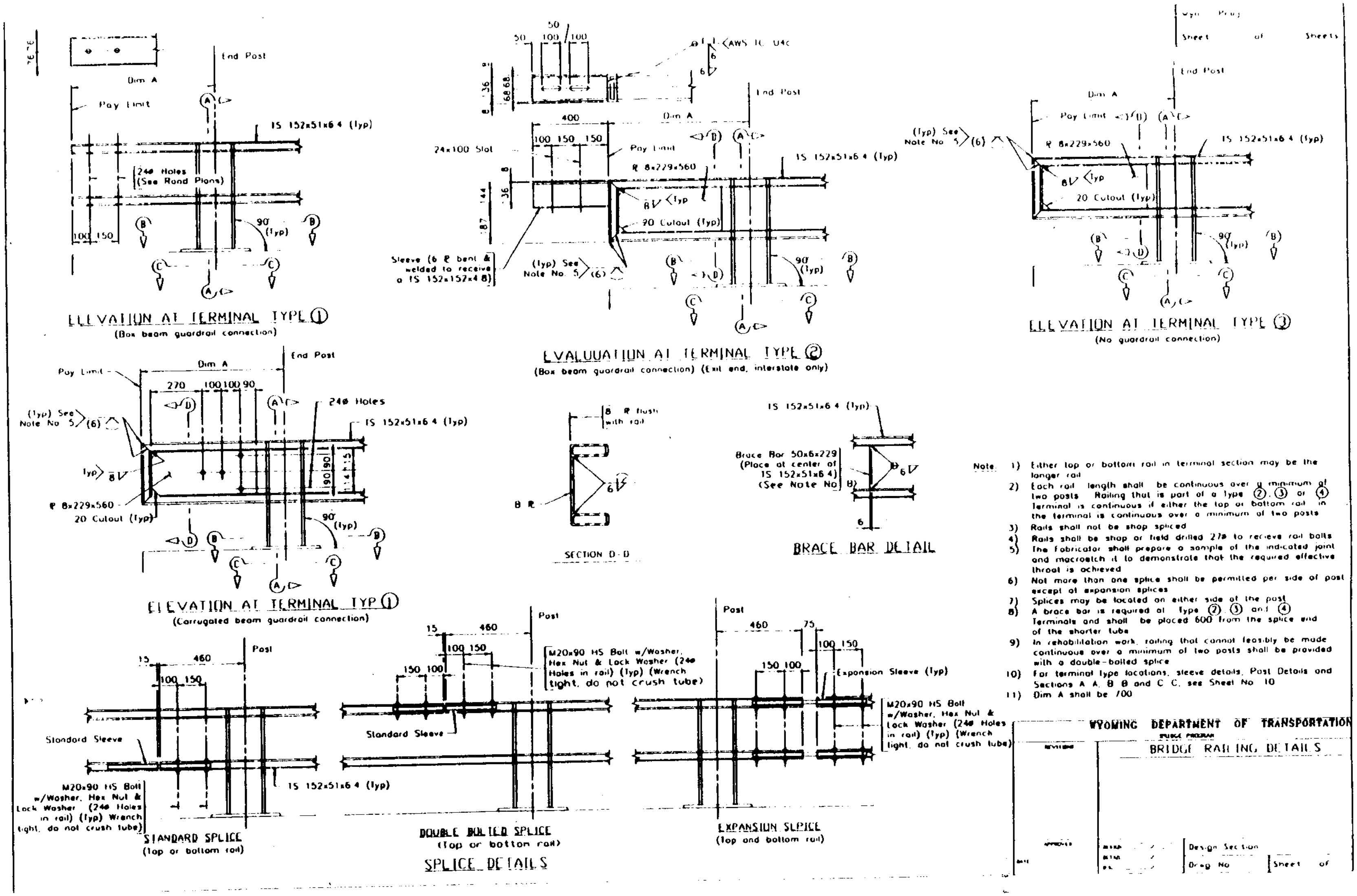
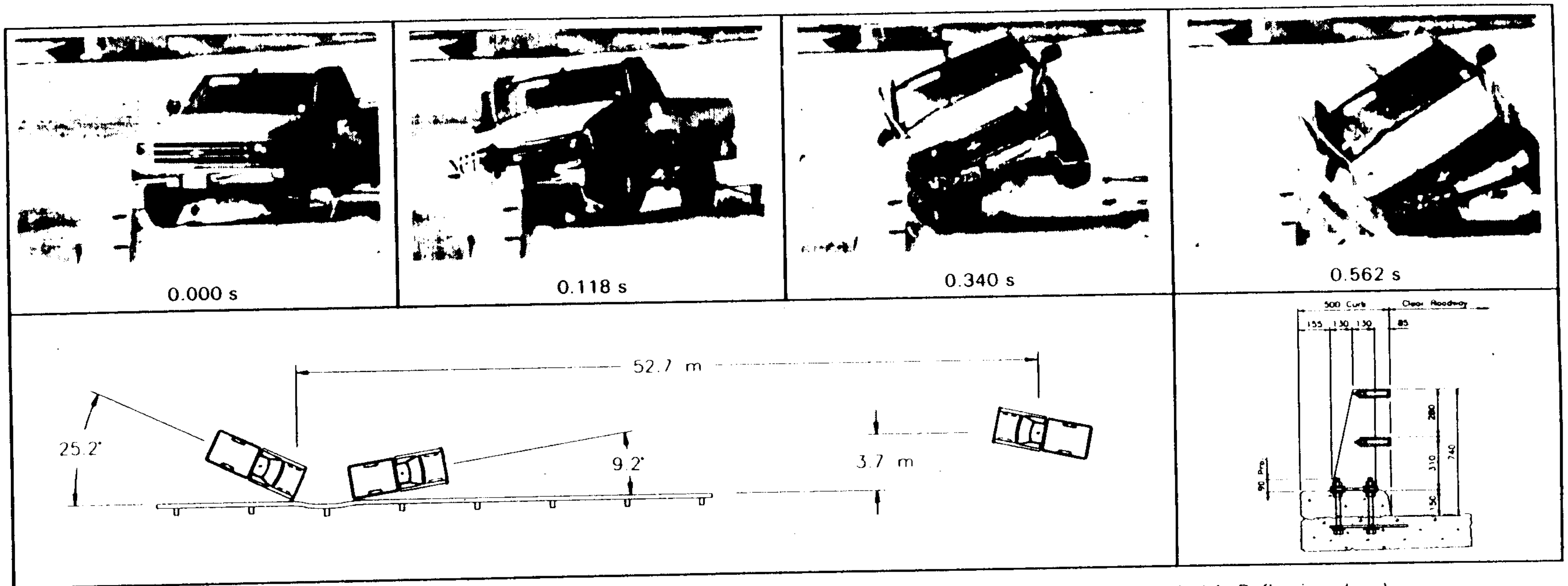


Figure 2. Details of the Wyoming 740WYBRAIL bridge railing elements.



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 472610-4
- Date 02/12/96

Test Article
- Type .... Bridge Rail
- Name 740WYBRAIL
- Installation Length (m) 23
- Size and/or dimension and material of key elements .... Tubular steel railing on concrete deck and curb

Soil Type and Condition ..... Concrete bridge deck, dry

Test Vehicle
- Type .... Production
- Designation 2000P
- Model .... 1989 Chevrolet 2500
- Mass (kg) Curb 2080
  - Test Inertial 2000
  - Dummy .... No dummy
  - Gross Static 2000

Impact Conditions
- Speed (km/h) 101.7
- Angle (deg) 25.2

Exit Conditions
- Speed (km/h) 65.5
- Angle (deg) 9.2

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.6
  - y-direction 7.7
- THIV (optional) ....
- Ridedown Accelerations (g's)
  - x-direction 4.6
  - y-direction .... -12.8
- PHD (optional) ....
- ASI (optional) ....
- Max. 0.050-s Average (g's)
  - x-direction .... -9.2
  - y-direction .... -12.1
  - z-direction .... -4.9

Test Article Deflections (mm)
- Dynamic .... N/A
- Permanent 51

Vehicle Damage
- Exterior
  - VDS 01RFQ5
  - CDC .... 01FREK4 & 01RYES4
- Interior
  - OCDI FS0112000
- Maximum Exterior Vehicle Crush (mm) 960
- Max. Occ. Compart. Deformation (mm) 92

Post-Impact Behavior
- Max. Roll Angle (deg) .... -12
- Max. Pitch Angle (deg) 4
- Max. Yaw Angle (deg) .... -43

Figure 14. Summary of results for test 472610-4.

Because of unavailability, A.S.T.M. A501, Hot-Formed Tubing, has been deleted from this guide and only A.S.T.M. A500, Cold-Formed Tubing, is shown.

Several years ago A.S.T.M. A500 tubular steel rail elements were dropped and fractured while being unloaded from a delivery truck. This unacceptable performance was judged to be the result of strain age embrittlement caused by the cold forming of the tubes and worsened by the galvanizing process they underwent. Inasmuch as not all steels are susceptible to embrittlement and barrier service experience had not revealed severe problems with embrittled material it was believed that many steels used in forming A.S.T.M. A500 tubes would result in serviceable rail elements. A modified A.S.T.M. E436 drop-weight tear test (DWTT), which is the basis for the modified test cited in this guide, was proposed as a means of screening out materials that would be subject to brittle fracture upon vehicle impact. (A subsize Charpy V-notch test could also have been selected.)

Modification of the test was necessary because some of the tube sizes to be tested were too small to obtain standard size specimens and some of the thin wall test specimens buckled rather than breaking under impact. Selection of the test temperature and the acceptance criteria was done somewhat arbitrarily, in that there was no testing to correlate vehicle barrier impact performance with DWTT results. The -18°C test temperature compares to service temperatures of -30°C that can be expected a few times a year in the State that instituted the test. In view of the fact that when the DWTT requirement was imposed the tube producers had to use different steels to consistently produce an acceptable product, one might infer, on the basis of past barrier experience, that the new requirement is probably conservative enough. If this assessment is true, it is probably so because relatively few barrier accidents occur below the test temperature, the tubes have significant impact toughness below the test temperature, the loading rates from vehicle impacts are lower than those in the DWTT, and the majority of tubes delivered have impact characteristics that exceed the required minimums.

It should be pointed out that the DWTT suggested in this guide was developed primarily for galvanized tubes that are subjected to the temperature of melted zinc. This temperature, in excess of 419°C, accelerates strain aging in susceptible materials so that the DWTT will reveal embrittlement in galvanized tubes. The same may not be true for corrosion resistant steels that are tested shortly after rolling. A way around this would be to artifically age the test specimens by holding them at an elevated temperature for sometime. Unless the literature contains guidance on this, some modest research would be needed to determine an appropriate temperature and time for aging specimens.

The consequence of imposing the DWTT requirement has been to increase the mill price of tubes about 10 to 15 percent over the basic cost of A.S.T.M. A500 tubes. However, if a fabricator cannot purchase a mill lot, about 40,000 pounds of steel, he will have to pruchase through a steel service center, which adds 25 to 30 percent to the mill tube price. At the present time service centers are not stocking tubes meeting the specifications in this guide. This could cause delivery delays while a service center assembles a mill size order. Currently, at least one mill is attempting to build a reserve of 5x3x0.25's, 6x6x0.188's, and 6x8x0.25's shown in this guide. The 6x2x0.25's also shown have not been in wide demand in recent years and may not be as easily obtained as the other sizes shown.

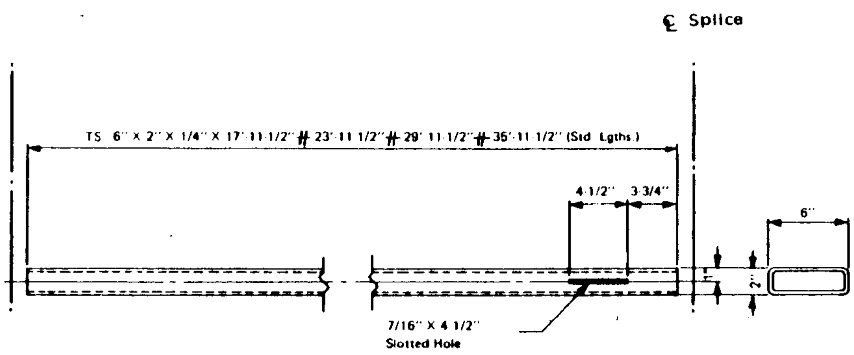
The typical method of producing A500 square and retangular tubes is to form and weld a flat plate into a circular tube and then reform the circular tube into a desired rectangular section. Tubes of different shape but of the same perimeter and wall thickness start out as the same size circular tubes. Thus, a 28-inch perimeter by 0.25-inch circular tube might become the 6x8x0.25 tube shown in this guide or a 7x7, a 12x2, or a 10x4. Likewise, a 24-inch perimeter x 0.188 wall circular tube might be formed into the 6x6x0.188 tube of the guide or a 4x8 or a 5x7. And the 6x20.25 and 6x3x0.25 tubes of the guide, both with 16-inch perimeters, would be similarly related to a 4x4 tube.

Mills have had experience producing 28-inch perimeter by 0.25 wall, 24-inch by 0.188 wall, and 16-inch by 0.25 wall tubes to the specifications shown in this guide and probably can and would produce any of the related tube sizes provided the order is of sufficient size. The minimum a mill is likely to roll is one coil or about 20,000 pounds. And as pointed out before, an order of this size would have to be purchased through a steel service center.

A designer calling for small quantities of the infrequently used sizes cited above is likely to be faced with an unavailability of material. Likewise, calling for tubes of other perimeters or wall thickness to meet these specifications is likely to be met with unavailability unless the order is of a large size or is likely to be repeated several times within a year or two.

The foregoing discussion was presented to point out that the specifications for tubular rail elements shown in this guide are intended to ensure a necessary impact toughness in tubular rail elements and that the specified materials are not standard stock items.

TUBULAR STEEL RAIL ELEMENTS TOUGHNESS REQUIREMENTS



STANDARD RAIL

SPECIFICATIONS

Rail elements shall conform to the requirements of A.S.T.M. A500, Grade B, as modified below and shall be galvanized in accordance with A.S.T.M. A123.

Rail elements from all heats supplied shall be tested in accordance with A.S.T.M. E436, Standard Method for Drop-Weight Tear Tests of Ferritic Steels, except as modified below.

Tests shall be done after all galvanizing and associated operations have been performed. Testing shall be conducted at a temperature of 18°C on 2" x 9" specimens supported to achieve a 7" span. Galvanizing shall not be removed from specimens.

The percentage shear area will be determined by testing eight specimens from the 6-inch side or sides not containing a weld. (Four specimens from each 6-inch side if both are unwelded.) The shear area of the specimen with the lowest shear area and the shear area of the specimen with the highest shear area shall be disregarded and the final average based on the remaining six specimens. If the average percent shear area falls below 50 the material represented by these tests shall be rejected, except that if the average shear area is 30 or greater one retest at a sampling frequency three times that of the first test and with no samples excluded in calculating the average will be permitted. Material not having an average percent shear area of 50 upon re-test shall be rejected. (See Appendix A.6 for discussion of specification.)

To facilitate acceptance and rejection of material, the manufacturer of the structural shape shall, before galvanizing, identify the product with the steel heat number, or some number that is traceable to the heat number, and his own unique identification code. The identification method shall be such that it can be read after the structural shape is galvanized. Identification marks shall be on only one face of the section, shall be no more than four feet apart, and shall not extend into the curved surface at the corners. The face marked shall not be the traffic face or its opposite.

No punching, drilling, cutting or welding will be permitted after galvanizing. No mill transverse welds will be permitted on the rail sections. Rail elements to be used in curves having radii of 1000 feet or less shall be shop formed to the required curvature.

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance, and accepted manufacturing practices.

INTENDED USE

The rail element is used in bridge railing designs BR1 (Steel) Type B and BR2 (Steel) Type B.

Note: It is suggested that this rail be mounted with a rail clamp, F-17-73. Designers wishing to weld studs directly to rails see Standard F-17-73 for stud and stud welding specifications.
Example designation is RE-31[23' - 11-1/2"] -76.

TS 6 X 2 X .25 RAIL

HM-TF-13 STANDARD | RE-31 [LENGTH DESIGNATION] -76

Enclosure 5 (Page 2 of 2)

SPECIFICATIONS

Rectangular tube bridge rail elements shall be manufactured from either ASTM A500 Grades A, B, or C cold-rolled tubing or ASTM A501 hot-rolled tubing as shown. ASTM A500 tubing is generally the most easily and economically obtained section but there have been reported problems with the steel fracturing at low temperatures. When using ASTM A500 steel it is highly recommended that the Drop-Weight-Tear test (ASTM E436) be performed to ensure each lot of material has adequate fracture toughness especially in regions that experience prolonged cold weather. ASTM A501 tubing can generally be used without the need for the Drop-Weight-Tear test. Holes in the tubes may be drilled or punched but if punched the punched side shall be placed next to the post. The box beams should be zinc-coated according to AASHTO M111 (ASTM A123). All welding shall conform to ANSI/AASHTO/AWS D1.5.

Designator	Area (10^3 mm^2)	I_x (10^6 mm^4)	I_y (10^6 mm^4)	S_x (10^3 mm^3)	S_y (10^3 mm^3)
RBM07a	1.54	2.19	1.39	42.9	36.6
RBM07b	1.99	2.71	1.70	53.1	44.7
RBM07c	2.41	3.12	1.96	61.2	51.6

Dimensional tolerances not shown or implied are intended to be those consistent with the proper functioning of the part, including its appearance and accepted manufacturing practices.

INTENDED USE

This rectangular tube bridge railing is the rail element in the SBB02a W- and-tube bridge railing. The tube is mounted on the PWF04 post using a 100-mm long FBX16a bolt and nut with an FWC16a washer.

RECTANGULAR TUBE BRIDGE RAILING

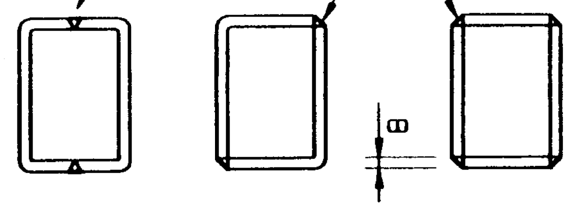
RBM07a-c

SHEET NO.	DATE
2 of 2	04-01-95

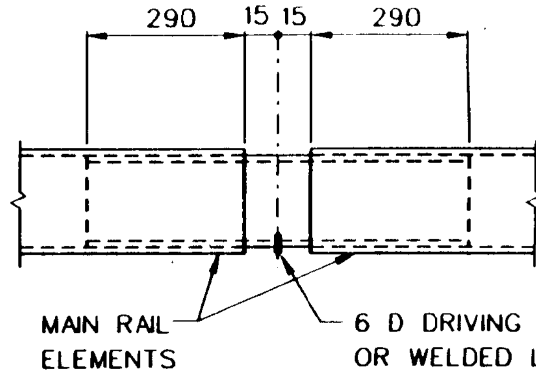
RECTANGULAR TUBE BRIDGE RAILING

1994

DESIGNATOR	A	B	MATERIAL
RBM07a	4.8	5	A500 GRADE C
RBM07b	6.4	6	A500 GRADE B
RBM07c	7.9	6	A500 GRADE A OR A501

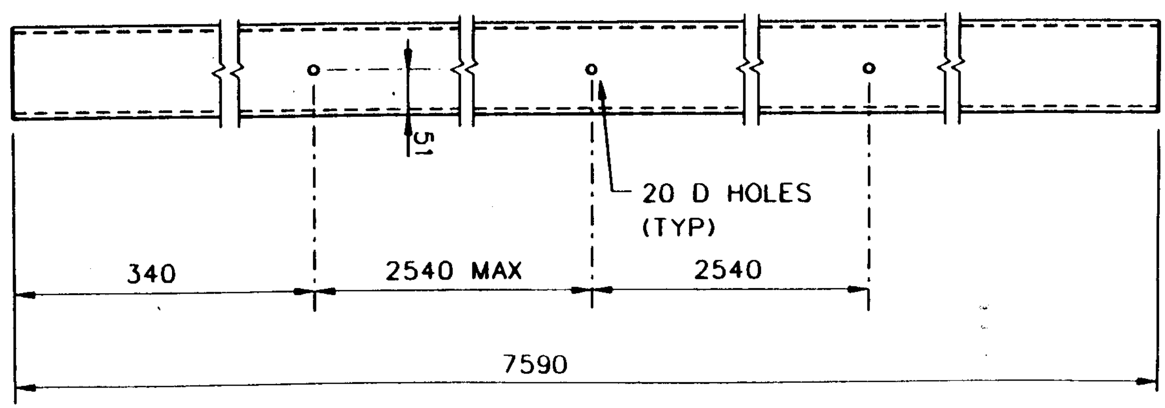


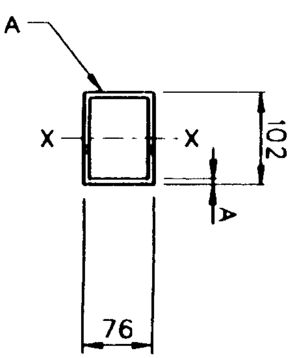
SLEEVE FABRICATION OPTIONS



THE DIFFERENCE BETWEEN THE OUTSIDE DIMENSIONS OF THE SPLICE SLEEVE AND THE INSIDE DIMENSIONS OF THE RAIL SHALL NOT EXCEED 3.

SPLICE DETAIL





ELEVATION

RBM07a-c

SHEET NO. 1 OF 2

REF. NO.