

Tow Bar Test Plan

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TARDEC

Engineering Business Group

Sustainment, Standardization, Transportability, and Recovery Team

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Purpose

The purpose of the tow bar test plan is to standardize the methods used to validate new tow bar ratings to ensure its durability and safety of use.

Definitions

Design load: The amount of load that the tow bar was designed for as predicted by analysis. The design load is used as a starting point for applying loads during lab testing.

Proof load: The worst case load condition that the tow bar can safely see during usage. Lab testing determines the tow bar's proof load by dividing the breaking load by a 1.5 factor of safety (FS).

Breaking load: The amount of load that exceeds the yield strength of the tow bar or any tow bar component. Breaking load shall be no less than 1.5 times the proof load.

Preliminary Tow Bar Rating: The calculated maximum Gross Vehicle Weight (GVW) that the tow bar can safely tow. This is estimated from the breaking load determined during lab testing and applicable factor of safety.

Tow Bar Rating: The actual maximum GVW that the tow bar can safely tow. This is determined through field and lab test comparisons, where the field measured proof load does not exceed the proof load as determined in the lab testing.

Gross Vehicle Weight (GVW): The weight of the vehicle when fully mission capable plus payload.

Test Requirements

Components Required

- No less than 6 complete tow bar assemblies are required for test
- Additional tow bar assemblies are required for adjustable length tow bars, new vehicle adapters, and non-symmetrical tow bars.
- Additional components may be required based on test results

Test Equipment Required

- Tension/Compression test machine

Vehicles Required

- 2 wheeled like vehicles as per field test procedure
- 2 tracked like vehicles as per field test procedure
- 1 recovery vehicle for wheeled vehicles

- 1 recovery vehicle for tracked vehicles (if different from like tracked vehicle)

Standards

- ASTM E1237 Standard Guide for Installing Bonded Resistance Strain Gages
- ASTM E1561 Standard Practice for Analysis of Strain Gage Rosette Data
- MIL-STD-1472 Human Engineering
- American Welding Society Structural Welding Code Books, i.e. AWS D1.1 (Structural Weld Code – Steel) or AWS D1.2 (Structural Weld Code – Aluminum)
- MIL-STD-810G Test Method Standards

General Pass/Fail Criteria

- Key features shall be measured at the end of each set of tests and shall be within design tolerance as specified on provided drawings. Measurements outside of the design tolerances shall be considered a failure. Key features are specified by the lead engineer and include, but are not limited to, weight, hole diameters, pin diameters, lunette diameter, clevis details, cross section, and overall length.
- Weld failures, voids, cracks, etc., shall be considered failures if identified visually or using a nondestructive weld inspection test method, per the applicable American Welding Society standard for the specific material being inspected.
- Broken or cracked components or catastrophic failures shall be considered failures.
- Any elongation, permanent deformation, or wear on any surface exceeding 1/8 inch shall be considered a failure.
- Lunette wear shall be uniform and the lunette shall continue to rotate about the pintle throughout the tests.
- At the discretion of the validating authority, tow bar failures during abuse testing may not necessarily constitute a failed tow bar and data may be used to determine tow bar and/or vehicle limitations.

Test Plan

Laboratory Tests

- 1) Serialize and photograph all tow bars and components.
- 2) Perform nondestructive weld inspection test on all tow bars to validate welds prior to any test.
- 3) Measure and record all key features determined by the lead engineer.
- 4) Grab Handle Breaking Strength: Using a tension/compression test machine, evaluate the grab handle as follows:
 - (a) Apply load to each tow bar handle that is equal to the weight of the tow bar and hold for 1 minute. A distributed load may be applied using a block that is no greater than 3” in width with rounded edges to simulate a female bare human hand, assuming a one-hand bar design. If mechanical assist aids (i.e. narrow hook

for hoisting) will be used to pick up the tow bar from the grab handles, the more severe load application shall be tested. (Reference MIL-STD-1472, Figure 42 for handle design criteria. One-hand bar handles are preferred for tow bar application.)

- (b) Repeat step (a) by incrementally increasing the load applied by 25% until the handle fails.
- (c) Record breaking strength. Passing criterion: breaking strength greater than or equal to 2 times the weight of the tow bar.
- (d) Photograph grab handles and tow bar, including break details and location.
- 5) Single Leg Tensile Breaking Strength: Using a tension/compression test machine, evaluate a single leg of one tow bar sample as follows:
 - (a) Apply strain gages to tow bar per figure 1, to record load versus strain. Reference ASTM E1237 and ASTM E1561 for general strain gage application information.
 - (b) Apply 25% of the intended design load in tension, pause and hold load for 20 seconds. Load shall be applied to the pintle attachment side of the tow bar leg and the fixture shall restrain the tow bar by simulating the attachment points (i.e. use pins sized to simulate the leg attachment to the pintle end and the leg attachment to the adapter end).
 - (c) Remove load and visually inspect part for failure. Discontinue test if a failure is identified and document failure as specified in step (e).
 - (d) Continue repeating steps (b) and (c) by incrementally increasing the load by 25% of the intended design load in tension until the tow bar fails.
 - (e) Measure key features and photograph the tow bar, including failure details.
- 6) Single Leg Compression Breaking Strength: Using a tension/compression test machine, evaluate a single leg of one tow bar sample as follows:
 - (a) Apply strain gages to tow bar per figure 1 to record load versus strain.
 - (b) Apply 25% of the intended design load in compression, pause and hold load for 20 seconds. Load shall be applied to the pintle attachment side of the tow bar leg and the fixture shall restrain the tow bar by simulating the attachment points (i.e. use pins sized to simulate the leg attachment to the pintle end and the leg attachment to the adapter end).
 - (c) Remove load and visually inspect part for failure. Discontinue test if a failure is identified and document failure as specified in step (e).
 - (d) Continue repeating steps (b) and (c) by incrementally increasing the load by 25% of the intended design load in compression until the tow bar fails.
 - (e) Measure key features and photograph the tow bar, including failure details.
- 7) Asymmetrical Single Leg Tensile/Compression Breaking Strength: If the tow bar legs are NOT identical or symmetrical, repeat steps 5 and 6 for the opposite tow bar leg.
- 8) Assembly Longitudinal Breaking Strength: Using a tension/compression test machine, evaluate a complete tow bar assembly, including all adapters, joints, and pins, as follows:

- (a) Apply strain gages to both legs of the tow bar per figure 1, and to the lunette and adapters per figure 2, to record load versus strain.
 - (b) Determine the MAXIMUM angle of tow bar spread, based on the intended towed vehicles' towing provisions. With each tow bar leg fixed to this maximum angle, set up the test fixture to apply the load to the lunette longitudinally. Refer to figure 3 for the appropriate test set up to apply the load. Load to the lunette shall be applied with a fixture that simulates a tow pintle. The adapter pins shall be connected to the test fixture to simulate the attachment to a vehicle's tow eyes.
 - (c) Slowly apply load in tension until the tow bar leg strain gage reading matches the value recorded from step 5b of the Single Leg Tensile Breaking Strength test. Pause and hold load for 20 seconds.
 - (d) Remove load and visually inspect part for failure. Discontinue test if a failure is identified and document failure as specified in step (h) below.
 - (e) Slowly apply load in compression until the tow bar leg strain gage reading matches the value recorded from step 6b of the Single Leg Compression Breaking Strength test. Pause and hold load for 20 seconds.
 - (f) Remove load and visually inspect part for failure. Discontinue test if a failure is identified and document failure as specified in step (h) below.
 - (g) Continue repeating steps (c) through (f) (above) by incrementally increasing the load to match the strain gage readings at each increment as tested in steps 5d and 6d until the tow bar fails. If the assembly's strength exceeds the single leg tow bar strength, testing may be discontinued.
 - (h) Measure key features and photograph tow bar, including failure details.
- 9) Assembly Lateral Breaking Strength: Repeat step 8 with a second complete tow bar assembly sample, but apply the load laterally in tension with the MINIMUM tow bar spread as shown in figure 4. During this test, one leg shall be in compression, and the other in tension, also shown in figure 4. Slowly apply the load incrementally until either the strain gage reading on the tensioned leg matches the value recorded from step 5, OR the strain gage reading on the compressed leg matches the value recorded from step 6.
- 10) Asymmetrical Assembly Lateral Breaking Strength: If the lunette or tow bar leg designs are NOT symmetrical, repeat step 9 for the opposite side of the lunette.
- 11) Proof Load and Preliminary Tow Bar Rating: Identify the worst case breaking load from steps 5 through 10 to determine proof load and the tow bar rating.
- (a) Calculate proof load using 1.5 factor of safety: $\text{Proof Load} = \text{Breaking load} / 1.5$
 - (b) Calculate preliminary tow bar rating using engineering judgment FS of 2.5:
 $\text{Preliminary tow bar rating} = \text{Breaking load} / 2.5$ (round down to nearest 5,000lbs). NOTE: Actual field test data is required to validate this number and the FS must be defined by the lead engineer. A FS of 2.5 is recommended based on tracked vehicle historical data, but shall never be less than 2.1.

- 12) Pre-Field Test Validation: Using a tension/compression test machine, evaluate each remaining complete tow bar assembly as follows:
- (a) Apply 50% tow bar rating in tension, pause and hold load for 20 seconds.
 - (b) Remove load and visually inspect part. Record any failures.
 - (c) Apply 100% tow bar rating in tension, pause and hold for 20 seconds.
 - (d) Remove load and visually inspect part. Record any failures.
 - (e) Apply proof load in tension, pause and hold load for 20 seconds.
 - (f) Remove load, inspect, and measure key features. Record any failures.
 - (g) Repeat steps (a) through (f) with the load applied in compression.
 - (h) Perform nondestructive inspection test on all tow bars to validate welds.
- 13) Adjustable Length Tow Bar and New Adapters: Additional testing is required if any of the following criteria apply (additional tow bars required):
- (a) Repeat steps 5 to 12 if the tow bar has one or more adjustable lengths and is usable in a retracted state – Test all usable adjustment positions unless directed to do otherwise by the lead test engineer.
 - (b) Repeat steps 8 to 10 for each additional vehicle adapter that the tow bar is compatible with that is new in design, not previously tested, or not in current Army inventory.
- 14) Sag: Evaluate sag requirement for retractable tow bars as follows per DOT 393.71:
- (a) With the tow bar fully retracted and supported at both ends, hang a weight equal to 0.5% of the tow bar rating (as determined in step 11b) from the center of the tow bar.
 - (b) Measure the amount of sag. A measurement exceeding 0.25 inches of sag in any direction shall constitute failure.
 - (c) Repeat (a) and (b) for each length adjustment and record.
- 15) Cold Climate Validation: Evaluate tow bar capabilities during cold weather exposure to ensure no significant reduction in load rating as follows:
- (a) Apply strain gages to the tow bar assembly, per step 8a.
 - (b) Soak the tow bar in a cold chamber at -50F for a minimum of 24 hours (Temperature per MIL-STD-810G).
 - (c) Set up the test fixture as in step 8b prior to removing the tow bar from the cold chamber.
 - (d) Remove the tow bar from the cold chamber and repeat steps 8b through 8h immediately. Test shall be completed within 1 hour of removal of the cold chamber.
 - (e) Document and compare results with those in step 8b through 8h. Results that show a degradation of greater than 10% may result in a tow bar rating decrease or additional tow limitations at the discretion of the lead engineer.

Field Tests

- 1) Determine and report the type of towed vehicles required for field testing with a GVW closest to the preliminary tow bar rating, as identified in step 11b of the laboratory testing:

- (a) Wheeled Vehicle – May be uploaded to match preliminary tow bar rating.
- (b) Tracked Vehicle – May be uploaded to match preliminary tow bar rating.

NOTE: Both wheeled and tracked vehicles shall be considered for tow bars that accommodate both. It is possible that the tow bar's rating will only require either wheeled vehicle or tracked vehicle testing, at the discretion of the test authority.

- 2) Determine and report the type of towing vehicles required for field testing:
 - (a) Wheeled like vehicle - Towing vehicle within 2,000lbs of the towed vehicle's GVW as determined in step 1a.
 - (b) Tracked like vehicle – Towing vehicle within 2,000lbs of the towed vehicle's GVW as determined in step 1b.
 - (c) Wheeled recovery vehicle – Recovery towing vehicle with GVW equal to or greater than the towed vehicle, as determined in step 1a, that provides the maximum vertical distance between the tow pintle of the towing vehicle and tow provisions of the towed vehicle (maximum angular displacement of the tow bar).
 - (d) Tracked recovery vehicle – Recovery towing vehicle with GVW equal to or greater than the towed vehicle, as determined in step 1b, that provides the maximum vertical distance between the tow pintle of the towing vehicle and tow provisions of the towed vehicle (maximum angular displacement of the tow bar).
- 3) Tow Hook Up Compatibility: Using the -10 operator manuals as guidance and the validated tow bars from step 12 of the laboratory testing, perform the necessary tow bar hook ups between the wheeled like vehicles including safety chains, electrical, and brakes. Document the hook ups through photographs.
- 4) Attach strain gages to each tow bar leg, lunette, and adapters, to record data.
NOTE: If the worst case load in the field exceeds the lab test proof load at any time during field testing, testing shall be discontinued until a lower GVW test vehicle can be identified for testing.
- 5) Compatibility and Handling: Complete the following tests and document results with photographs:
 - (a) Validate tow bar permits motion in both horizontal and vertical between the towed and towing vehicles (i.e. lunette rotates around tow pintle freely and allows for connection between vehicles of different tow lug/pintle heights)
 - (b) Maximum braking effort from 15mph, 25 mph, 35 mph, and 45mph (two times each)
 - (c) Downhill braking from 5mph on 20% and 30% grade
 - (d) Turning on 20% and 30% grade
 - (e) Vertical step 6 inch (in.), 12 in., 18 in., forward, ascending and descending

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- (f) Figure-8 turning, 10 times
 - (g) 90-degree left and right turns
 - (h) Towing in reverse: Tow the vehicle in reverse with the vehicles' centerlines within three inches of straight for no less than 50 feet. Turn the vehicles so that the vehicles are at an angle of approximately 45 degrees until the vehicles are 180 degrees from the starting point. Continue straight in reverse for 50 feet. Turn the vehicles opposite to the previous turn with the vehicles at a 45 degree angle to each other until the vehicles are 180 degrees from starting point. Continue straight in reverse for 50 feet.
 - (i) Tracking test per DOT 393.71, number 7.
- 6) Compatibility and Handling - Continued: Repeat steps 3 to 5 for the following:
- (a) Designated wheeled recovery vehicle and wheeled towed vehicle
 - (b) Tracked like vehicles
 - (c) Designated tracked recovery vehicle and tracked towed vehicle
- 7) Endurance: Complete endurance testing using one tow bar sample for heaviest GVW like vehicle tow combination (tracked or wheeled) while recording strain gage data through the first and last lap of each course. Tow bar shall be inspected, measured, and photographed, as appropriate, after completing each course. Vehicle Technical Manuals (TM) shall be referenced for safe operating speeds.
- (a) Paved road (25 miles)
 - (b) Level gravel road (50 miles)
 - (c) Hilly gravel road (50 miles)
 - (d) Level trails (35 miles)
 - (e) Hilly trails (40 miles)
 - (f) Cross Country (40 miles)
 - (g) Rock Ledge (10 miles)
 - (h) Belgian Block (5 miles)
 - (i) Repeat steps (a) to (h) using the same tow bar with the heaviest recovery/towed vehicle combination (tracked or wheeled) with 1 lap of strain gage data being recorded. Note: After collecting and analyzing data for both tow combinations, the worst case scenario can complete the total mileage versus a strict split between the two combinations if required due to vehicle availability or efficiency.
- 8) Additional Endurance: Repeat no less than 1 lap of each course identified in step 7 with strain gages if the following criteria applies:
- (a) Tow bar usage includes a tracked or wheeled vehicle combination that was not tested in step 7. Both like vehicle and recovery/towed vehicle combinations need to be tested.
 - (b) The tow bar has one or more adjustable lengths and is usable in a retracted state - All adjustment positions shall be tested.
 - (c) Additional vehicle adapter(s) are compatible with the towed vehicle that are new in design, not previously tested, or not in current Army inventory – Test each.

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- 9) Abuse: Complete abuse testing including the following and document results with photographs:
 - (a) Structural integrity: With the tow bar assembly on a concrete surface, run over the middle of the tow bar with the towed vehicle and then run over the female end of the tow bar with the towed vehicle.
 - (b) Mire jerk (with strain gages attached): Mire the towed vehicle to a mire factor 1; while still connected for tow, reverse the towing vehicle, and attempt to jerk the mired vehicle out.
 - (c) Extreme service use (with strain gages attached): 1 lap of Churchville B at maximum safe speed.
 - (d) Tow bar installed upside down, if applicable.
 - (e) Drop test: Drop tow bar assembly from 5 feet high onto a concrete surface:
 - i. Retracted (stowed) – lunette end first
 - ii. Retracted (stowed) – vehicle adapter end first
 - iii. Retracted (stowed) – horizontally
 - iv. Extended – lunette end first
 - v. Extended – vehicle adapter end first
 - vi. Extended - horizontally
- 10) Post Field Test Validation: Visually inspect, measure key features, and photograph the tested tow bars at the completion of tests.
- 11) Complete final nondestructive inspection test of the tow bars to validate welds.
- 12) Post Field Test to Tow Bar Rating and Proof Load: Using a tension/compression test machine, evaluate the endurance tested tow bar to the tow bar rating and worst case load in the field as described in the laboratory test steps 8 and 9.
- 13) Post Field Test to Tow Bar Tensile Failure: Using a tension/compression test machine, evaluate the endurance tested tow bar to tensile failure as described in the laboratory test step 8.
- 14) Actual Tow Bar Rating: Using strain gage data from both laboratory and field testing, determine the actual tow bar rating:
 - (a) If worst case load in field is less than or equal to the lab test proof load, tow bar rating shall be defined as the tested towed vehicle GVW.
 - (b) If worst case load in the field is greater than the preliminary lab test proof load, field testing shall be completed with a lower GVW vehicle.
 - (c) Validate that the tow bar rating meets or exceeds the design factor of safety as determined by the lead engineer. Recommended FS is no less than 2.1 for wheeled vehicle applications and 2.5 for tracked vehicle applications.

Compatibility Tests - Vehicle Level

- 1) Identify vehicles that can be towed using the tow bar through the maximum tow bar rating, as identified in step 14 of the field testing.

- 2) For each vehicle that can be towed using the tow bar, compatibility testing shall be completed between like vehicles and vehicles capable of flat towing the vehicle. Pending testing authority approval, a test waiver may be granted for:
 - (a) Vehicle tow combinations similar to those already tested (similar GVW, tow bar angular displacement, and tow provision spread)
 - (b) Towed vehicles with significantly less GVW than the tow bar's rating.
- 3) Compatibility Tests:
 - (a) Field test plan steps 3 through 8, but only for a minimum of 1 lap of each endurance test course
 - (b) Cramp angle steering to determine maximum turning radius
- 4) Validate that the maximum load seen in the field for each vehicle tow combination is within the designated proof load to ensure the tow bar's rating is not exceeded per step 14 of the field testing.
- 5) Tow Bar Stowage: Evaluate tow bar stowage to validate stowage retaining brackets
 - (a) Properly stow and secure the tow bar to the test vehicle.
 - (b) Verify retention of the tow bar (i.e. measure fastener torque, key features, position) and photograph.
 - (c) Test drive 20 miles of cross country or vehicle shaker equivalent at the safe towing speed identified in the vehicle's TM.
 - (d) Verify retention is the same post-test (i.e. re-measure fastener torque, key features, position) and photograph.
 - (e) Evaluate tow bar accessibility.
 - (f) Evaluate tow bar stowage location for clearance for performing lift tow operations.

Additional Tow Bar Test Considerations

Document any concerns, comments, discrepancies, feedback, etc. in a written report with photographs, if applicable, for the following:

- 1) Human Factors Engineering (HFE) feedback (Reference MIL-STD-1472) – Recommendation is to complete this prior to testing.
 - (a) Grab handle size, placement, and usage
 - (b) Ease of lift and stow
 - (c) Handling safety
 - (d) Number of Soldiers required to move tow bar
 - (e) Pinch hazards
 - (f) Proper labeling if one-person lift is exceeded
- 2) ILS feedback: Special tool requirements and training requirements
- 3) Technical Manual validation for both operator and field maintenance, if available
- 4) DOT 393.71 certification markings
- 5) Environmental testing per MIL-STD-810G; requirements/tests determined by lead engineer.

Appendix

Figure 1: Tow Bar Leg Strain Gage Locations – Example

**Actual locations and resulting figure to be provided by test authority for each specific tow bar

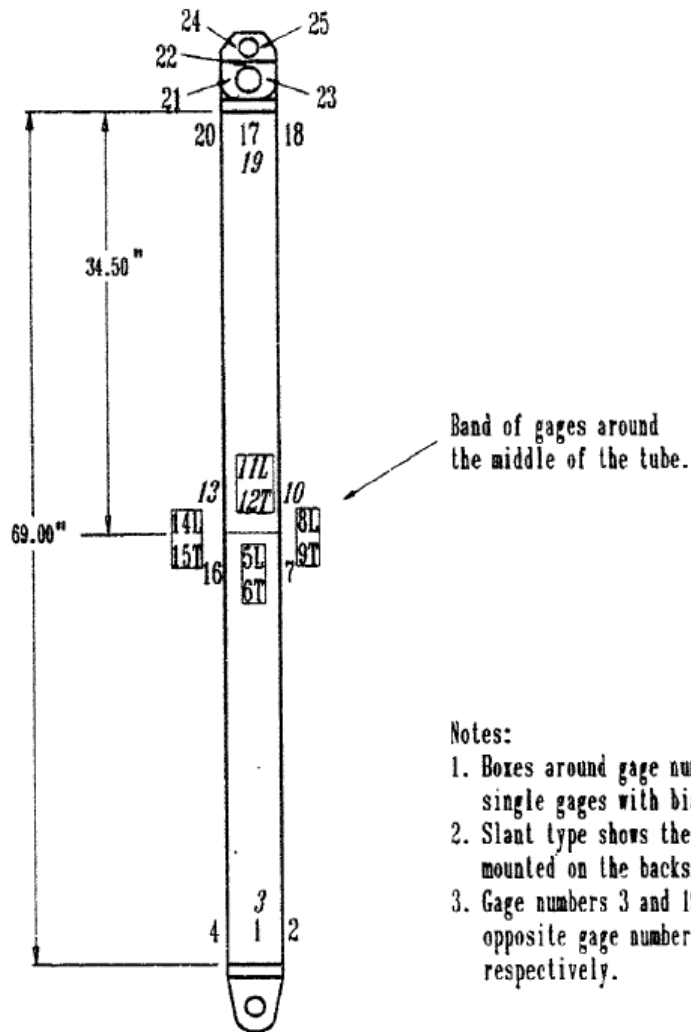


Figure 2: Tow Bar Assembly Strain Gage Locations – Example

**Actual locations and resulting figure to be provided by test authority for each specific tow bar

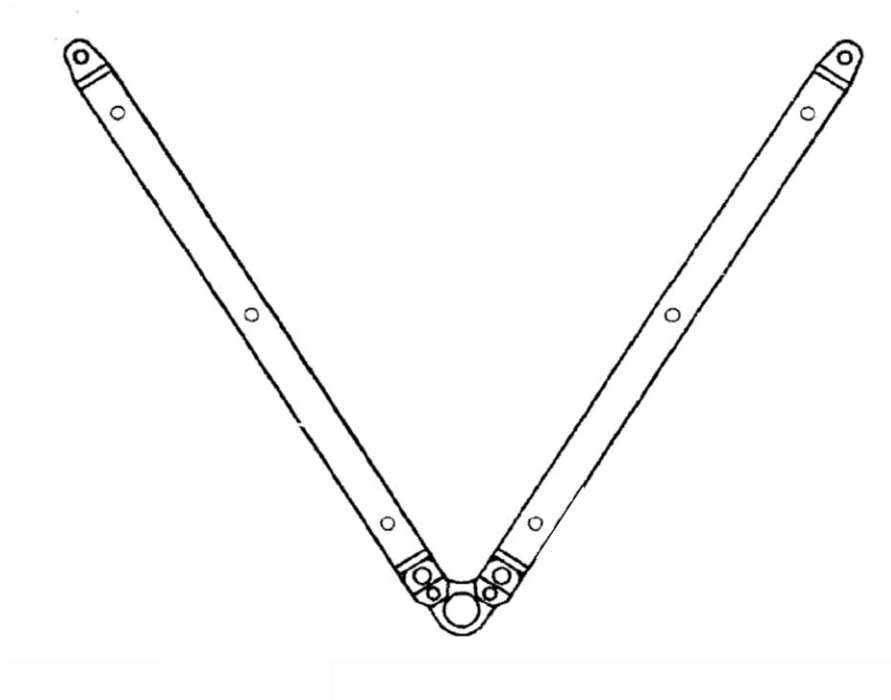
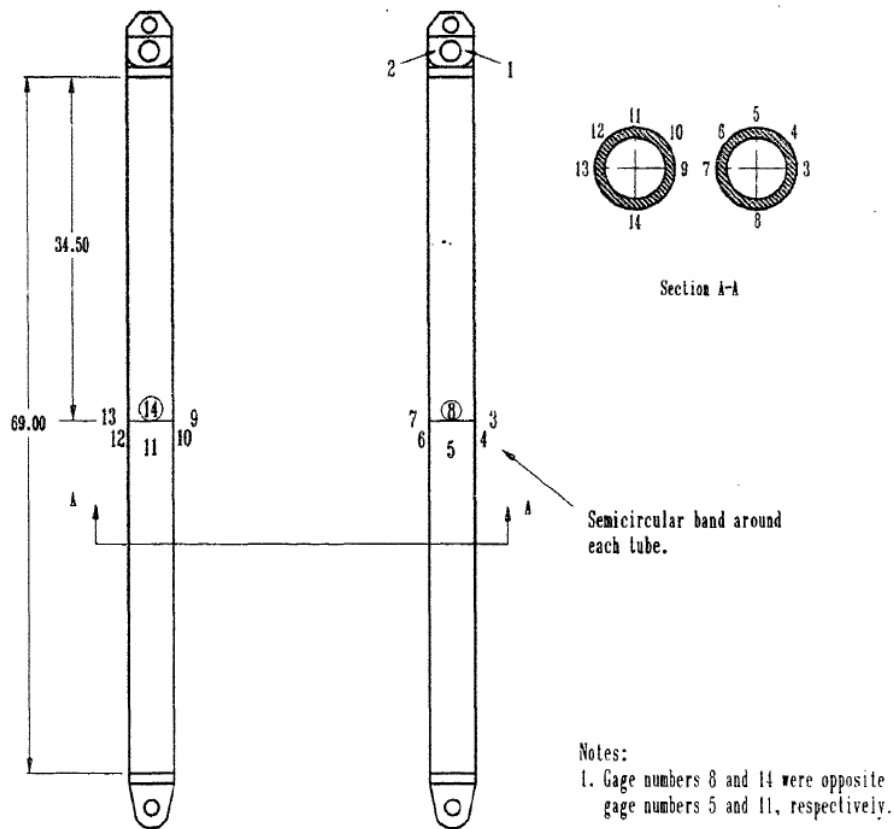


Figure 3: Longitudinal Tow Bar Assembly Test Set up

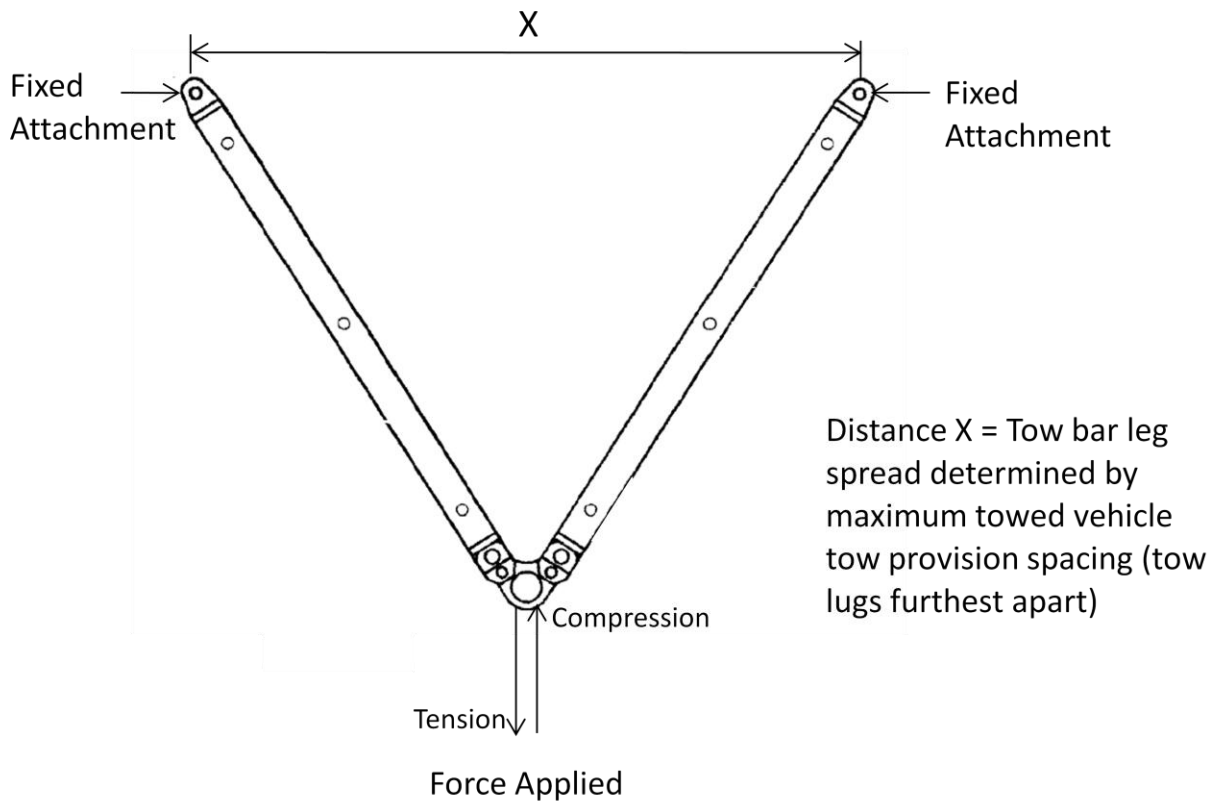


Figure 4: Lateral Tow Bar Assembly Test Set up

