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This TOP describes accepted methods used to measure, analyze, and report the towing and recovery capabilities of self-recovery, like-vehicle recovery, and dedicated recovery vehicles. Test procedures include safety, performance, and durability.

15. SUBJECT TERMS
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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 02-2-618 — 9 October 2018
DTIC AD No.

TOWING AND RECOVERY

*This TOP supersedes TOP 02-2-131 Recovery Vehicles, Full-Tracked, dated 26 March 1973.

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1. SCOPE.

1.1 Purpose.

This Test Operations Procedure (TOP) describes accepted methods to measure, assess, and report the towing and recovery capabilities of self-recovery, like-vehicle recovery, and dedicated recovery vehicles. Test procedures include safety, performance, and durability testing.

1.2 Background.

a. Recovery is defined as retrieving immobile, inoperative, or abandoned equipment and returning it to operation or to a maintenance site for repair (Army Techniques Publication No. 4-31)[1**]. Recovery actions typically involve a combination of towing, lifting, or winching. Recovery consists of three potential scenarios. Self-recovery actions require using only the disabled equipment's on-board assets. Like-recovery involves assistance from the same or heavier class vehicle. Dedicated-recovery actions require assistance from a vehicle specifically designed and dedicated for recovery operations.

b. According to current Army doctrine, a self-recovery winch can be used only to recover the equipment on which it is mounted. Self-recovery winches should not be used to recover other mired equipment. Like-vehicle recovery is attempted when self-vehicle recovery is insufficient. The principle is to use another piece of equipment of the same weight class or heavier to extract or tow the mired equipment using towbars, chains, or tow cables. Towing with cables or chains can be used for extraction only to a safe are where a towbar can be connected and towed. When self-recovery and like-recovery are not practical or are unavailable, dedicated recovery assets are needed. Dedicated recovery vehicles are used when self-recovery or like-vehicle recovery is not possible due to the severity of the situation or safety considerations.

c. Towing is limited to moving the equipment to the nearest unit maintenance collection point. A military towbar has a much different use compared to their commercial counterparts. Commercial towbars are used primarily for driveaway-towaway operations. They see a small percentage of use compared to other commercially accepted methods of towing and recovery. Rarely are they used off-road and towed vehicle damage is typically limited to powertrain failures where the towing resistance is not significantly increased.

d. Military operations vary and can require towing/recovery over multiple terrain features and environmental conditions for extended periods of time and/or distance. Towed vehicle damage can be significant where a loss of tires, wheels, suspension components, or tracks are common. This type of damage creates a drastic increase in towing resistance, coupled with extreme terrain features like grades, obstacles, and low soil strength, the towbar forces can be significant.

** Superscript numbers correspond to Appendix C, References

e. Military towbars are typically designed for a specific weight range of vehicles and the towing vehicle. Many vehicles are mission specific and have attributes designed specifically for recovery such as heavy duty cooling systems, high capacity axles, suspension lockouts, etc. Typically, tactical vehicles have a requirement to tow a “like” vehicle. Specific attention should be given to this requirement as the vehicle family’s mission profile, terrain, and speed profiles can dictate a robust towbar design.

1.3 Limitations.

a. The procedures outlined in this TOP apply to conventional designs of wheeled and tracked vehicles operating on test courses such as those described in TOP 01-1-011B Vehicle Test Facilities at Aberdeen Test Center and Yuma Test Center[2]. Additional natural and prepared test environments may be required to evaluate unique vehicle designs, attributes, or to address specialized mobility requirements or mission profiles.

b. Tests referenced in this TOP are designed to evaluate the towing and recovery attributes of recovery specific components as integrated into a vehicle. The recovery hardware may perform differently than the component manufacturer claims due to the integration on the specific vehicle.

c. The testing and use of Allied Kinetic Energy Recovery Ropes (AKERR) are not covered in this TOP. The ropes are a multi-strand, woven, nylon rope used for like-vehicle extraction. The rope is connected between the mired vehicle and the towing vehicle. The towing vehicle accelerates, stretching the rope, which creates potential energy. When the rope is fully stretched, it transfers the energy to the mired vehicle, giving it a strong, sudden pull.

d. The testing of chains and rigging are not included in this TOP. The tester must ensure that accepted rigging techniques are being followed and appropriate hardware are used. There are several types and grades of chains in use, ranging from grade 30 through 100. To ensure safe recovery operations, only grades 80 or 100 chain shall be used. The chain grade is usually stamped on several links throughout the length of the chain.

e. The crane/boom stability test procedure should be used only for those load ratings that are based on stability factors and are not applicable to those ratings that are based on structural limits. The tester should take care to assure that tests are made only in the least stable direction for the rating under test.

2. FACILITIES AND INSTRUMENTATION.

2.1 Calibration.

a. All measuring tools and instrumentation will be calibrated against a higher order standard at periodic intervals not to exceed twelve months. Records, showing the calibration traceability to the National Institute of Standards and Technology (NIST), will be maintained for all measuring and test equipment.

b. All measuring and test equipment and measuring standards will be labeled with the following information:

(1) Date of calibration.

(2) Date of next scheduled calibration.

(3) Name of the organization and technician who calibrated the equipment.

c. A written calibration report will be provided that includes the following information:

(1) Type of equipment, manufacturer, model number, etc.

(2) Measurement range.

(3) Accuracy.

(4) Calibration interval.

(5) Type of standard used to calibrate the equipment (calibration traceability of the standard must be evident).

2.2 Recommended Criteria.

The criteria presented for the towing and recovery devices are presented for use in inspections, tests, and analysis where vehicle specific criteria are not provided or are deemed inadequate.

2.2.1 Towing Devices.

a. Title 49, Transportation Federal Motor Carrier Safety Regulation (FMCSR) 393.71 Subpart F-Coupling Devices and Towing Methods[3] provide basic design criteria for towbars. Society of Automotive Engineers (SAE) J2512, Surface Vehicle Recommended Practice Towing Equipment Ratings and Practices[4] establishes guidelines for rating towing and recovery equipment and carriers. It is applicable to all towing and recovery equipment manufacturers. SAE J706, Rating of Winches[5] applies to winches that are primarily designed for intermittent pulls and lifts and whose configuration and condition are the same as when they were shipped by the manufacturer. They are not intended to be used in any manner for the movement of personnel. Specific criteria from the above references are presented below.

b. Towbars, Jointed. The towbar shall be so constructed as to freely permit motion in both horizontal and vertical planes between the towed and towing vehicles. The means used to provide the motion shall be such as to prohibit the transmission of stresses under normal operation between the towed and towing vehicles, except along the longitudinal axis of the tongue or tongues (FMCSR 393.71).

c. Towbar Fastenings. The means used to transmit the stresses to the chassis or frames of the towed and towing vehicles may be either temporary structures, bumpers, or other integral parts of the vehicles: Provided, however, that the means used shall be so constructed, installed, and maintained that when tested as an assembly, failure in such members shall not occur when the weakest new towbar which is permissible, is subjected to the tests given therein (FMCSR 393.71).

d. Means of Adjusting Length. On towbars, adjustable as to length, the means used to make such adjustment shall fit tightly and not result in any slackness or permit the towbar to bend. With the towbar supported rigidly at both ends and with a load of 23 kilograms (kg) (50 pounds (lb)) at the center, the sag (measured at the center) in any direction shall not exceed 6 millimeters (mm) (0.25 inches (in.)) under any condition of adjustment as to length (FMCSR 393.71).

e. Method of Clamping. Adequate means shall be provided for securely fastening the towbar to the towed and towing vehicles (FMCSR 393.71).

f. Towbar Connection to Steering Mechanism. The towbar shall be provided with suitable means of attachment to and actuation of the steering mechanism, if any, of the towed vehicle. The attachment shall provide for sufficient angularity of movement of the front wheels of the towed vehicle so that it may follow substantially in the path of the towing vehicle without cramping the tow-bar. The towbar shall be provided with suitable joints to permit such movement (FMCSR 393.71).

g. Tracking. The towbar shall be so designed, constructed, maintained, and mounted as to cause the towed vehicle to follow substantially in the path of the towing vehicle. Towbars of such design or in such condition as to permit the towed vehicle to deviate more than 3 in. to either side of the path of a towing vehicle moving in a straight line as measured from the center of the towing vehicle are prohibited (FMCSR 393.71).

h. Marking Towbars. Every towbar acquired and used in driveaway-towaway operations by a motor carrier shall be plainly marked with the following certification of the manufacturer thereof (or words of equivalent meaning):

(1) This towbar complies with the requirements of the Federal Motor Carrier Safety Administration for (maximum gross weight for which towbar is manufactured) vehicles.

(2) Allowable Maximum Gross Weight.

(3) Manufactured (month and year) by (name of manufacturer).

NOTE: Towbar certification manufactured before the effective date of this regulation must meet requirements in effect at the time of manufacture (FMCSR 393.71).

i. Safety Devices in Case of Towbar Failure or Disconnection.

(1) The towed vehicle shall be connected to the towing vehicle by a safety device to prevent the towed vehicle from breaking loose in the event the towbar fails or becomes disconnected. When safety chains or cables are used as the safety device for that vehicle, at least two safety chains or cables shall be used. The tensile strength of the safety device, and the means of attachment to the vehicles, shall be at least equivalent to the corresponding longitudinal strength for towbars. If safety chains or cables are used as the safety device, the required strength shall be the combined strength of the combination of chains and cables (FMCSR 393.71).

(2) If chains or cables are used as the safety device, they shall be crossed and attached to the vehicles near the points of bumper attachments to the chassis of the vehicles. The length of chain used shall be no more than necessary to permit free turning of the vehicles. The chains shall be attached to the towbar at the point of crossing or as close to that point as is practicable (FMCSR 393.71).

(3) A safety device other than safety chains or cables must provide strength, security of attachment, and directional stability equal to, or greater than, that provided by safety chains or cables installed in accordance with the previous paragraph. A safety device other than safety chains or cables must be designed, constructed, and installed so that, if the tow-bar fails or becomes disconnected, the tow-bar will not drop to the ground.

j. Limitation Considerations for Towing.

(1) The Gross Combination Weight Rating (GCWR) of the towing vehicle must be equal to or greater than the sum of the towing and towed vehicles (SAE J2512).

(2) The Gross Axle Weight Ratings (GAWR) of the front and rear axles should not be exceeded (SAE J2512).

k. The maximum recommended lift load for stable steering for each equipment and chassis combination, as determined by the retained front axle weight can be calculated as shown in Equation 1 (SAE J2512).

$$\text{Lift Load} = \frac{(1 - K) * FA * WB}{OH} \qquad \textit{Equation 1}$$

where:

FA = the weight on the front axle, including driver, without any towing load.
K = the desired percentage of the towing vehicle front axle weight remaining when the load is lifted.
OH = the distance from the centerline of the rear axle(s) to the lift point.
WB = the wheelbase of the chassis.

l. The required rear axle capacity for each equipment and chassis combination can be calculated as shown in Equation 2 (SAE J2512).

$$\text{Required GAWR (rear)} = \frac{(WB + OH) * LR}{WB} + RA \qquad \textit{Equation 2}$$

where:

LR = the lift rating.
OH = the distance from the centerline of the rear axle(s) to the lift point.
RA = the rear axle weight of the completed vehicle with all equipment.
WB = the wheelbase of the chassis.

m. Chassis, terrain, weather, and road conditions can affect the proper “K” factor. Historically, industry practice is to use a “K” factor of 0.50 (50%) for general purpose towing under non-adverse conditions (SAE J2512).

2.2.2 Recovery Devices.

a. The structural design of the recovery equipment must have a higher load capacity than the performance rating(s) (SAE J2512).

b. Winch ratings shall be published in the towing and recovery equipment manufacturer’s specifications. Winches shall conform to, or exceed, the requirements of SAE J706[5]. All new winches introduced into commerce for towing or recovery applications shall conform to or exceed, the requirements of SAE J706, as amended and adopted. Wire rope/cable size, rated breaking strength, working limit, type, and class, should be specified by the towing recovery equipment manufacturer (SAE J2512).

c. All ratings for wire rope/cable and chain assemblies are for the undamaged assembly condition and must comply with SAE J959[6] (SAE J2512).

d. Sheave pitch diameter to wire rope/cable diameter ratios should be a minimum of 8 to 1. Boom support wire rope/cables that are static under load should have a minimum sheave to cable ratio of 6 to 1 (SAE J2512).

e. The safety brake system will be capable of automatically and continuously holding rated load when power is not being delivered to the winch. When lowering a load under power, it will operate automatically and have adequate thermal capacity to control rated load at rated speed for a distance of 15.2 meters (m) (50 feet (ft)) without appreciable loss of effectiveness due to temperature rise. Any loss other than that due to normal wear is expected to return when the brake cools. Adjusting means, automatic or manual, will be provided to compensate for wear of friction materials. When raising a load, the safety brake will automatically release and not generate an appreciable amount of heat (SAE J706).

f. The drum release clutch, if provided, will be a positive-engagement type; friction-type clutches are not acceptable. Automatically applied means such as springs, detents, or angled jaw faces will be provided to ensure that the clutch will not slip out of engagement under load (SAE J706).

g. A drum drag brake will be provided if a drum release clutch is not provided. Its purpose is to prevent the drum from overrunning the wire rope when "free-spooling," and it will not be relied on to control or hold a load (SAE J706).

h. The drum diameter will be at least eight times the maximum recommended wire rope diameter (SAE J706).

i. The duty cycle rating is the total number of meters (feet) of wire rope travel at rated line speed, and one-half rated line pull to achieve a temperature rise from 38 to 121 °Celsius (°C) (100 to 250 °Fahrenheit (°F)), or, if the temperature stabilizes below 121 °C (250 °F), the duty cycle is the stabilization temperature (SAE J706). See Section 6.2 for the procedure to establish the duty cycle rating.

j. The sheave diameter should be as large as possible, and except for very flexible rope, never less than 20 times the wire rope diameter (Technical Manual (TM) 3-34.86)[7].

k. Cable rigging should avoid reverse bends whenever possible. When reverse bends are unavoidable, the block or drum should be sized larger than normal. Space the bends as far apart as possible to allow more time between rope reversals (TM 3-34.86).

2.3 Instrumentation.

Towbar instrumentation, as required, should be installed and calibrated using TOP 02-2-606[8] as a guide.

Devices for Measuring	Permissible Measurement Uncertainty
True ground speed (velocity)	± 0.2 kilometer per hour (km/hr) (± 0.1 miles per hour (mph))
Global Positioning System (GPS)	± 2.5 m (8.2 ft)
Wheel or sprocket speed	± 0.5% of full-scale range
Engine speed	± 0.5% of full-scale range
Drawbar/pintle force	± 0.5% of full-scale range
Temperature measuring devices	± 2 °C (4 °F)
Angular velocity	± 0.5% of full-scale range

Devices for Measuring	Permissible Measurement Uncertainty
Acceleration	± 5% of measurement
Approach/Departure and Ramp Breakover angles	± 5% of measurement

2.4 Facilities.

a. The facilities outlined in this TOP are described in TOP 01-1-011B. Additional natural and prepared test environments may be required to evaluate unique vehicle designs and attributes, or to address specialized mobility requirements or mission profiles. Unique off-road test areas should be defined by a cone penetrometer versus depth profile, grain size distribution data, Atterburg limits, and the percent moisture at the critical layer. Refer to TOP 02-2-619A Soft Soil Mobility[9] for additional detail.

b. Safety and performance tests are typically conducted on paved level areas with sufficient length to safely reach the required speeds while towing another vehicle. Adequate width should also be provided to handle any unexpected controllability issues associated with emergency braking or adverse vehicle handling. Gradeability limitations should be determined using paved longitudinal grades and side slopes prior to attempting any off-road or cross country operations. Use of an adequately sized holdback vehicle is recommended for downhill braking and controllability tests on grades exceeding 20 percent.

c. Endurance operations are conducted on test courses that represent the terrain features of the recovery vehicle and the towed vehicles' mission profile. Limits on gradeability and ground speed should be determined using the results from the safety and performance tests.

d. The safety and performance tests of recovery specific assets require a paved area of sufficient length to stage the recovery vehicle, winch cable, and a holdback vehicle or dynamometer truck. The road surface should be dry and clean to maximize the available friction for consistent winch loading and dynamometer traction.

e. Testing hoist winches often require special loads of specific weight and/or dimension. The test plan or requirements documentation should be consulted when designing the payloads. Consideration should also be given to the test site elevations. Most hoist winches have a requirement to recover over an embankment and the supplied cable length is adjusted accordingly. The test site should have the required height differential or the cable must be shortened to simulate winching on the bare drum.

3. REQUIRED TEST CONDITIONS.

3.1 Preparation for Test.

3.1.1 Inspection of Towing and Towed Vehicles.

a. Inspection of the towing and towed vehicles is conducted as described in TOP 02-2-505[10], with emphasis given to the condition of the powertrain, suspension, tires, or tracks. The towing provisions of the towed vehicle should be checked using a non-destructive inspection to ensure weld quality. Bolted provisions should have all fasteners checked for proper torque and marked to allow for future visual checks. The pintle and associated mounting hardware should be inspected for weld quality, proper fastener torque and preload. The pintle should rotate without binding or excessive torque within the mounting provision.

b. New tires or track are typically provided, but often worn tires and grousers are used to analyze the loss of towing performance due to wear. In all cases the exact condition of the components are documented. Perform necessary tests to optimize track tension or tire pressure. Consider the operating terrain and the additional loading imposed by the towed vehicle. Simulated vehicle damage can be introduced to the towed vehicle to analyze any increase in motion resistance and its impact to the towbar and/or towing vehicle.

c. All of the tires must have operated on a road or track at least 160 km (100 miles) prior to the test. Tires must have at least 75 percent of the tread remaining, and the tread must be in good condition. Tire pressures should be verified for the intended operation, and the Central Tire Inflation System (CTIS), if so equipped, should be set for the terrain. Tracked vehicles should follow the recommended track break-in procedure for the vehicle type, and the track tension should be adjusted prior to the start of the test.

d. Each vehicle should be configured with the basic issue items (BII) as determined by its mission role. Recovery specific vehicles typically have more tools and rigging equipment stowed than other military vehicles. Once the payload and stowage requirements are verified, the following characteristics should be determined at a minimum. Other measurements may be needed to characterize the vehicle, based on the specific design/build.

(1) Weight distribution.

(2) Center of gravity.

(3) Overall width, length, and height.

(4) Wheelbase and axle spacing.

(5) Pintle location with respect to axle location.

(6) Front/rear overhang.

(7) Ground clearance profile.

(8) Angles of approach, departure, and ramp breakover.

(9) Towing provision locations with respect to the center of gravity.

e. Record the inspection data on a report form appropriate to the vehicle (e.g., Department of the Army (DA) Form 2404 or DA Form 5988E). Take characteristic photographs of the towing combination and record weights and dimensions of the vehicles using TOP 02-2-500[11] as a guide. Record the weight distributions using TOP 02-2-801[12] as a guide. Measure the center of gravity of the towing and towed vehicles using TOP 02-2-800[13] as a guide.

f. Ensure that all test personnel are familiar with the required technical and operational characteristics of the item and with the required test procedures.

3.1.2 Inspection of Towbars and Associated Hardware.

a. TOP 02-2-606 should be used as a guide for the inspection and preparation of towbars and associated hardware used in towing tests.

b. Inventory and photograph all towbars and associated brackets.

c. Nondestructive weld inspections will be performed on all towbars to validate all welded components prior to any test.

d. All key features are measured and recorded for each towbar. Key features of the towbar and associated hardware include component weights, hole/pin diameters, lunette diameter, clevis end details, cross section, overall tube length, wall thickness, and straightness.

3.1.3 Characterization/Inspection of Wire Winch/Hoist Ropes.

3.1.3.1 Wire Rope Characterization.

a. The basic element of wire rope is the individual wire. Wires are laid together to form strands and the strands are wound together to form rope. Individual wires are typically wound together in the opposite direction of the lay of the strands. Strands are then wound around a central core that support and maintain the position of strands during bending and load stresses. There are three types of wire rope cores.

(1) Fiber rope.

(2) Independent wire rope cores.

(3) Wire strand cores.

b. Wire rope is classified by the number of strands, the number of wires per strand, the strand construction, and the type of lay.

3.1.3.2 Lubrication of Wire Rope.

a. At the time of manufacture, a lubricant is generally applied to the rope. The principal functions of lubricants are to reduce friction as the wires move over each other and to provide corrosion protection and lubrication in the core, inside wires and external surfaces. Prior to adding additional lubrication, the rope should be cleaned by scraping or steam cleaning. Rust should be removed at regular intervals with a wire brush. The rope should be lubricated with a good grade of oil free of acids and alkalis, and should be light enough to penetrate between the wires and strands. Both penetrating and coating lubricants should be used. Lubricant can be brushed on or passed through a trough containing the lubricant. Apply it as uniformly as possible along the length of the rope.

b. Petrolatum lubricants provide excellent corrosion and water resistance. Petrolatum lubricants maintain their consistency well in cold environments but can drip off at higher temperatures.

c. Asphaltic coatings generally dry to a dark hardened surface, which makes inspection more difficult. They adhere well for long-term storage but can crack and become brittle in cold environments.

d. Various types of greases are used for wire rope lubrication. These typically penetrate partially but usually do not saturate the rope core. Greases used for this application generally have a soft semifluid consistency.

e. Petroleum and vegetable oils penetrate best and are the easiest to apply because proper additive design of these penetrating types gives them excellent wear and corrosion resistance. The fluid property of oil type lubricants helps to remove external contaminants.

f. If the lubrication interval is not specified, daily inspections during endurance testing should be conducted to develop the appropriate interval. The interval should be specified in the number of full length pulls.

3.1.3.3 Installation of Wire Rope.

a. The cable length should be calculated using the drum dimensions and the required freeboard (Figure 1). For grooved drums the acceptable freeboard is two times the rope diameter or 5 centimeters (cm), whichever is greater. For smooth drums the freeboard should be two times the rope diameter or 6.5 cm, whichever is greater. The calculated rope length should be compared to the system requirement, if available.

b. More than three layers of rope on the drum results in reduced rope life and may cause crushing and severe abrasion of the bottom layer, and at the transition points between layers. On drums with multiple layers, difficulty may be experienced transitioning from the bottom to second layer. Wedging and severe abrasion of the rope is a common problem. Good drum design incorporates a tapered steel filler to transition the rope smoothly.

c. Attention should be given to the anchor. With the hook or load at its lowest point, there should be two or three complete wraps of cable (dead wraps) on the drum unless the manufacturer’s guidance is more. Figure 2 shows an example of a simple tackle system.

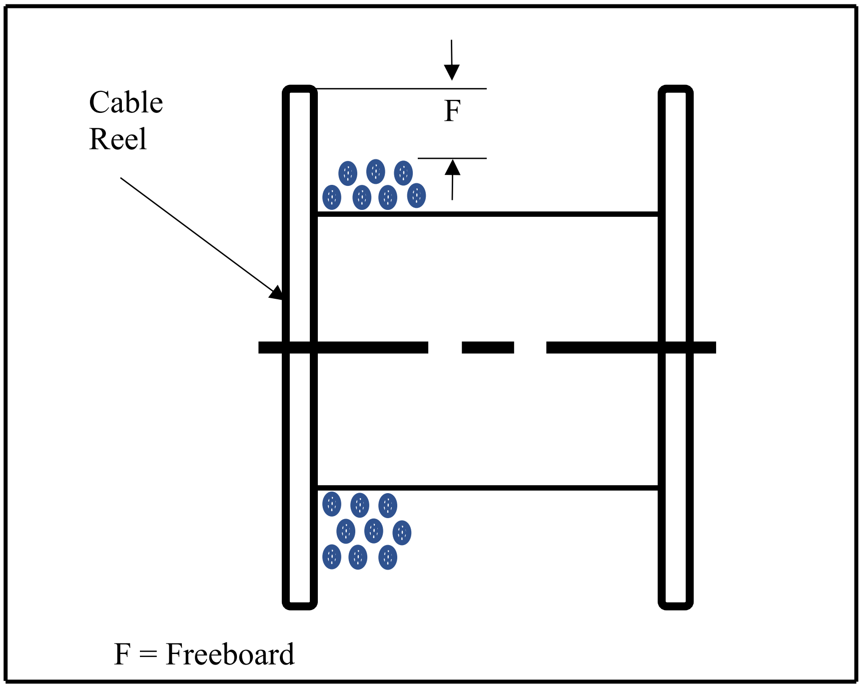

Figure 1. Freeboard diagram.

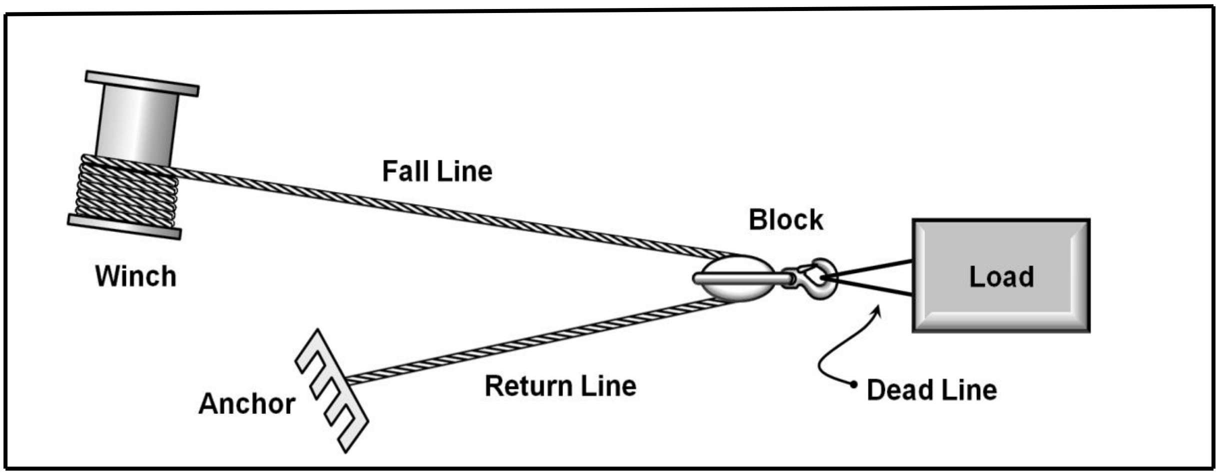

Figure 2. Simple tackle system[1].

d. When winding a rope on the drum ensure that it bends in the same direction. It is also necessary to apply a preload to assure good spooling. Validate the rope anchor point on the drum using the following procedure for the specific rope being installed.

(1) Determine whether the rope is overwound or underwound on the drum.

(2) If right lay rope is being installed visualize yourself standing behind the drum.

(3) Make a fist with your right hand to simulate the drum and extend your forefinger to represent the cable.

(4) For overwound rope keep the back of your fist up. Your extended finger simulates the cable coming off the top of the drum.

(5) For underwound rope turn your palm up. Your extended forefinger simulates the cable coming off the bottom of the drum.

(6) The extended forefinger always points towards to the flange to which the rope should be secured.

(7) For left lay ropes use the above procedure replacing the right hand with the left hand.

3.1.3.4 Measurement of Fleet Angle.

a. The fleet angle (Figure 3) is the angle between a line drawn from the center of the sheave, or fairlead edge, through one flange of the drum and a line through the center of the sheave. In some installations the fleet angle may be different, left and right. The larger of the two angles must be used. The generally accepted standards for fleet angles are:

(1) 0.25 to 1.25 degrees for grooved drums.

(2) 1 to 2 degrees for smooth drums.

b. If the fleet angle is larger than recommended, the rope may rub excessively against the edges of the sheave, or crush and abrade the rope winding on the drum. Severe scuffing of grooved drums is possible as the rope wears against the groove lands. This action also bruises and crushes the rope.

c. If the fleet angle is too small the rope typically piles up against the drum flange damaging the rope and/or winch drum. Small angles can also cause excessive rope vibration accelerating fatigue as it winds on the drum.

3.1.3.5 Wire Rope Inspection.

a. Winch and hoist ropes should be inspected at regular intervals throughout testing. During performance and safety tests, the rope should be inspected after every pull. During endurance tests, an inspection interval should be selected that coincides with the cooling period, if possible. The cooling period should be based on recommendations from the manufacturer. Time for rope replacement is indicated by the extent of abrasion, scrubbing, and peening on the outside wires, broken wires, evidence of pitting or severe corrosion, kink damage, or other mechanical abuse resulting in distortion of the rope structure. A narrative describing the rope history should include type of tests performed, e.g., stall pulls, brake check, 50 percent line speed, the number of pulls, and the total time under load.

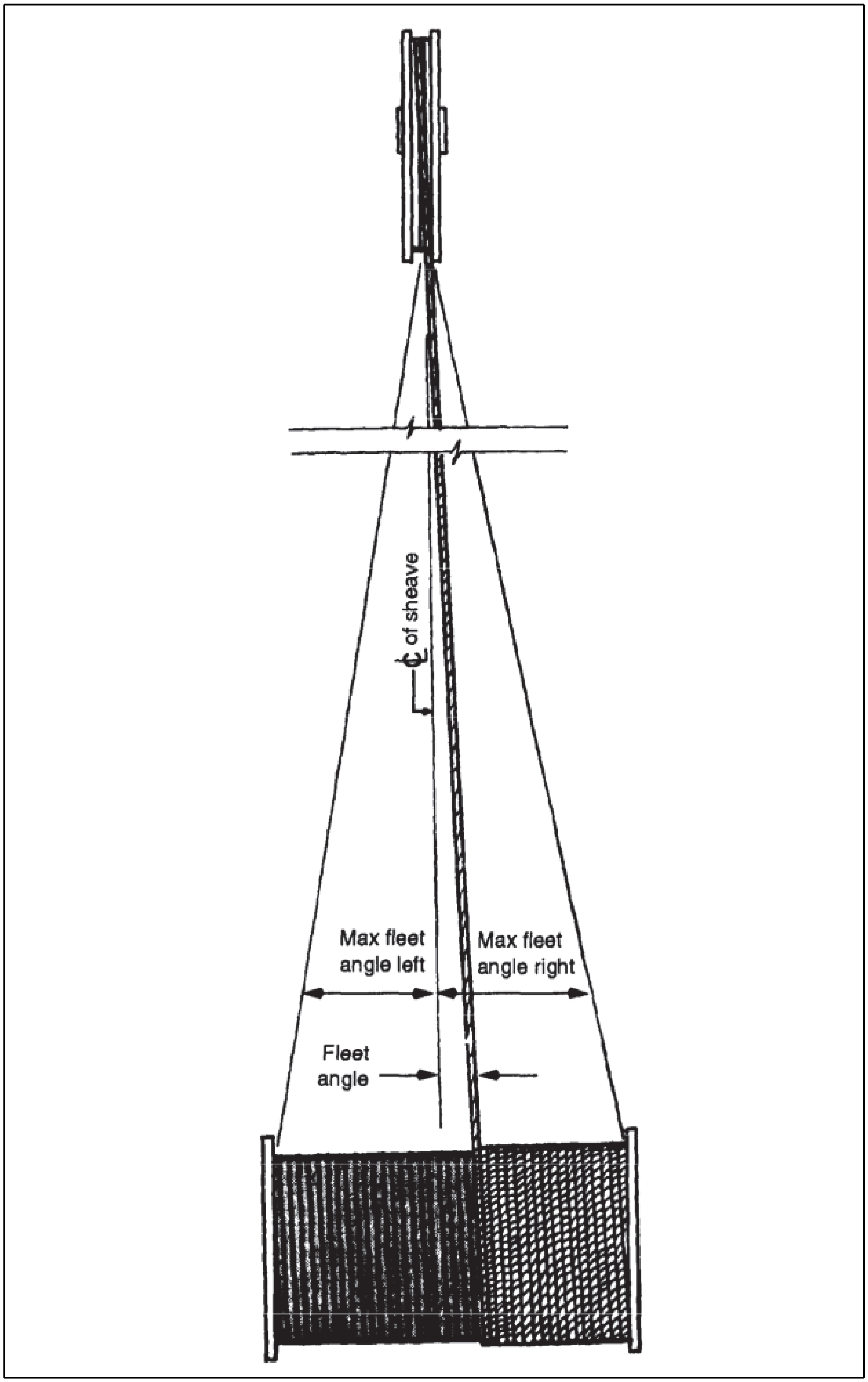

Figure 3. Fleet angle[7].

b. The following conditions are sufficient to immediately remove the rope from service. Refer to SAE J959 for detailed wire rope inspection procedures.

(1) Corrosion. Wire rope deterioration from corrosion or heat should be cause for replacement.

(2) Broken Wires.

(a) An occasional broken wire may be found early in the rope's life and should not dictate rope replacement, as long as the failures are at well-spaced intervals. Note the area and watch for additional wire breaks as the test progresses. Broken wire ends should be removed by bending the offending wire back and forth with pliers.

(b) In running ropes, a rope must be replaced if there are six or more randomly distributed broken wires in one rope lay, or three or more broken wires in one strand in one rope lay. For rotation resistant ropes having eight or more outer strands, two broken wires in six rope diameters or four broken wires in thirty rope diameters constitute replacement. In pendants or standing ropes, evidence of more than one broken wire in one rope lay require replacement.

(c) Wire breaks occurring on the crowns of outside wires indicate normal degradation. Breaks occurring in the valleys between strands indicate an abnormal condition where fatigue or breakage of other wires may not be readily visible. One or more valley break in one rope lay constitute a rope failure. Broken wires near an attached fitting are cause for concern and the rope should be replaced.

(3) Worn and Abraded Wires. Wear due to friction over sheaves, rollers, and drums cause the outer wires to become flat on their outer surface. The worn areas become void of lubrication and are characterized by a bright appearance. This is considered normal deterioration. Rope replacement is necessary if the wear exceeds 1/3 of the diameter of the wire.

(4) Reduction of Rope Diameter. Any marked reduction in rope diameter is a sign of critical deterioration. It is often due to excessive wear of the outer wires, loss of the internal core support, corrosion, inner wire failures, or loosening of the rope lay. Ropes should be replaced if the diameter is reduced by more than:

(a) 1 mm (3/64 in.) for rope diameters up to 19 mm (3/4 in.).

(b) 1.5 mm (1/16 in.) for rope diameters of 22 to 28.5 mm (7/8 to 1-1/8 in.).

(c) 2.4 mm (3/32 in.) for rope diameters of 32 to 38 mm (1-1/4 to 1-1/2 in.).

(5) Rope Stretch. Excessive wire rope stretch is another sign of critical deterioration. An approximate elongation of 15 cm per 30 m (6 in. per 100 ft) of rope is normal in six strand ropes. Elongations of up to 25 cm per 30 m (10 in. per 100 ft) are normal for eight stranded ropes. Lengthening of the rope lay and/or a reduction in rope diameter are signs of rope stretch.

It is typically caused from rope overloading or a loss of strength as the rope approaches the end of its life cycle.

(6) Sheaves, guards, guides, drums, flanges, and other surfaces contacted by wire rope during operation should also be examined at the time of inspections. Any condition harmful to the rope in use at the time should be corrected. The same equipment, and particularly sheave and drum grooves, should be inspected and placed in proper condition before a new rope is installed.

3.1.3.6 Break-in.

Several full-length pulls are recommended at light loading and reduced speed. This permits the rope to gradually adjust to the required configuration and enables the strands to become seated. Some increase in rope length due to an increase in length of the rope lay and a slight decrease in rope diameter is expected as the strands and core are compacted. Ropes with a fiber core can increase in length by as much as 1/2 percent. Steel core ropes will increase in length by 1/4 percent.

3.1.4 Characterization/Inspection of Synthetic Winch/Hoist Ropes.

3.1.4.1 Synthetic Rope Characterization.

Synthetic rope can provide strength comparable to wire rope while exhibiting superior abrasion and corrosion resistance. Most synthetic rope can be used over relatively small bending surfaces compared to wire rope. Typical synthetic rope construction and common fiber types are outlined below. Many ropes are a blend or mixture of multiple fiber types. Combinations of polyester and polypropylene fibers in ropes are common (Rigging Manual, Construction Safety Association of Ontario[14]).

3.1.4.2 Synthetic Rope Construction.

a. 3-Strand Twisted Rope. A three-strand rope consists of 3 equal sized strands that are in turn comprised of smaller twisted yarns. The strands are twisted together in either a right or left lay to form the final rope. The manufacturing process produces an inherent torque in the rope. A load suspended from a 3-strand rope will tend to rotate and will unravel the rope unless a swivel is used. The torque can also form kinks if the rope is unloaded quickly. The strands are large and form a prominent spiral on the rope surface. Due to the rough surface, abrasion is concentrated on the exposed strands and can lead to premature failure of a rope in an application requiring extensive cycling over sheaves, or in service where the contact with a rough, irregular surface is a normal occurrence.

b. Plaited or Eight Strand Rope. Plaited rope consists of 4 right- and 4 left-lay strands combined in pairs and plaited together. Because of the mixed lay construction there is no inherent torque and it resists rotation. The individual strands are significantly smaller than the strands in an equally sized 3- strand rope. Under load, this type of construction tends to assume a square cross section that causes the strands to become very pronounced along the length of the rope. This trait promotes accelerated abrasion when the rope contacts sheaves, rollers, and drums.

c. Parallel Core Rope. Parallel core rope consists of a core strength member that is made up of numerous rope bundles aligned with the longitudinal axis of the rope. The bundles are covered by an external sheath that is typically a braided or extruded jacket. The core handles most of the load imposed on the rope while the jacket holds the rope together. Parallel core rope is used with larger sheaves and drums to keep from overstressing the outer bundles. Sheave diameters should be at least 20x the rope diameter.

d. Single-Braid Rope. Single or hollow braid ropes consist of multiple strands combined in a cylindrical braid pattern. Single braid ropes are typically manufactured in 12- or 16-strand configurations. This type of construction is torque neutral. The strength is higher than 3-strand or plaited ropes of equivalent diameter. The strands are smaller than those used in 3-strand or plaited construction making them more flexible and less prone to abrasion. Under load, the rope retains a more circular cross section.

e. Double-Braid Rope. Double braided ropes are constructed using an inner cylindrical braided core structure that is covered by an outer cylindrical braid. The design of the rope is such that the cover and the core braids share the rope load. The construction is torque neutral and will not kink in service. Because of the high fiber mass, this rope design is significantly stronger for a given size than three-strand or plaited ropes. Depending on the fiber it may equal or exceed a parallel core rope in strength. Double braid rope is extremely flexible and provides a smooth uniform surface that is highly abrasion resistant. Many double braid designs provide surface fibers parallel to the longitudinal axis of the rope further enhancing the abrasion resistance.

3.1.4.3 Synthetic Fiber Description.

a. Many synthetic ropes look alike, specifically in regards to material. Users frequently encounter ropes of unknown rope material. Fiber rope properties such as strength, elongation, and durability are primary characteristics of the material. Substitution of ropes of the wrong composition can have disastrous consequences in recovery operations.

b. The four most common rope materials are nylon, polyester, polypropylene, and high modulus fiber. Many ropes are manufactured using combinations of several materials.

(1) Nylon is generally the strongest of the common materials when dry. Nylon ropes can lose as much as 20 percent of their strength when wet. Two forms of nylon are used in ropes; nylon 6 and nylon 6.6. The properties of these fibers, and the ropes made from them, are not significantly different, with the exception of nylon 6 having a lower melting temperature.

(2) Polyester ropes are almost as strong as nylon when dry. Polyester retains its strength when wet.

(3) Polypropylene is the most common material found in ropes used in the marine field. It is attractive because it is lighter than water and floats. It is the least expensive of the synthetic fibers but is not very heat, ultraviolet (UV), or abrasion resistant.

(4) Polyethylene is uncommon in large ropes.

(5) Ropes that are made of higher strength fiber materials are grouped together in a category called high modulus fibers. Sometimes the fiber material is described by its trade name instead of its common name. Some rope manufacturer’s trade names also identify the material. Aramid was the first high modulus fiber. It is known by the trade names Kevlar and Twaron. High Modulus Polyethylene (HMPE) is a special form of the conventional polyethylene and is much stronger and stiffer than conventional polyethylene. It is known by the trade names Spectra and Dyneema. Light and medium recovery ropes are typically Spectra or Dyneema.

3.1.4.4 Synthetic Rope Identification.

a. Preliminary identification can sometimes be made by the fiber appearance. This is generally not a reliable way of determining the fiber identity, but it is helpful in narrowing the number of possible fibers.

b. Polyester fibers and almost all nylon fibers are very fine and hair like, typically about 0.023 mm in diameter. These fibers are almost always white. It is virtually impossible to distinguish between nylon and polyester by appearance alone. HMPE and the multifilament form of polypropylene are very similar to nylon and polyester in appearance.

c. A monofilament form of nylon (trade name: Perlon) is 3 to 6 mm in diameter and is found in some European ropes. The fiber is round, stiff, and larger in diameter than heavy pencil lead. It is usually mixed with the multifilament form of nylon in rope making.

d. Polypropylene is encountered in several different forms in ropes. It is sometimes a thin multifilament fiber, similar to but slightly thicker than polyester and nylon. It is sometimes a thicker monofilament, resembling straw or bristles, typically 0.1 to 0.15 mm in diameter. In this form it may either be a continuous fiber, or it may be cut into short lengths and then processed like natural fibers to form staple yarn. Another form of polypropylene resembles a thin tape, typically 0.06 to 0.1 mm thick. The tape is sometimes twisted so it appears to be a circular fiber. This tape may be fibrillated or split so it appears to be a collection of small flat fibers that cling to each other.

e. Ropes made of monofilament polypropylene are frequently black, orange, or yellow. The dye helps to prevent UV degradation. White monofilament polypropylene fibers with some other form of UV protection are also common.

f. Multifilament polypropylene fibers are usually white. They resemble nylon and polyester fibers in appearance, except they are usually slightly thicker and stiffer. This contrast may be evident in mixed fiber ropes.

g. Polyethylene fibers typically are bristle-like and are 0.2 to 0.4 mm in diameter. Polyethylene is not damaged by ultraviolet effects so it is usually not dyed. Its natural color is white. However, colored polyethylene is common, especially yellow and orange. It is difficult to distinguish polyethylene from monofilament polypropylene by appearance.

h. Aramid is a very fine straw-colored fiber. Almost all large aramid ropes have a braided jacket of nylon or polyester, or are covered by an extruded polyurethane coating. The individual strands are usually jacketed.

i. HMPE is a fine slippery fiber. Most HMPE ropes are jacketed, but many are unjacketed. Sometimes a light dull-blue coating is processed onto an unjacketed HMPE rope.

3.1.4.5 Internal Marker Tapes.

a. Many synthetic ropes have a marker tape buried within a strand. Marker tapes typically have the name of the manufacturer, the type of material, and the year of manufacturer. Not all rope manufacturers include, or are required to have, markers in their rope products. In a double braid rope, the tape is usually in the center of the core or between the core and the cover. In other ropes, the tape is usually in the strand that has the colored marker yarn. The marker tape is a conclusive way of identifying a rope material, when it can be found. The marker tape can be found by untwisting the end of a strand. In a broken rope, it may be found by careful disassembly of the rope. It may be difficult to find and examine the marker tape in a spliced rope in service.

b. Table 1 shows the marker yarn color code specified by the International Organization for Standardization (ISO) for identifying fibers in ropes[15]. Unfortunately, this material color code is not commonly followed. Some rope manufacturers identify their ropes by various color marker yarns, and some of these manufacturer's markers also identify the rope material.

TABLE 1. STANDARD MATERIAL MARKERS (ISO)

YARN COLOR	FIBER TYPE
Blue	Polyester
Green	Nylon (polyamide)
Red	Polypropylene
Orange	Polyethylene

c. As shown in Table 2, the international "standard" marker yarn material code colors are duplicated by some rope makers for other purposes. Caution should be taken in using such marks as a means of identifying rope materials.

TABLE 2. MANUFACTURER ROPE MARKING

MARKER DESCRIPTION	MANUFACTURER
1 red and 1 green yarn	Samson/American
1 red, 1 white, 1 blue yarn	Columbia ropes
black yarn	Marlow Ropes
1 red, 1 white, 1 blue yarn	Bexco Le Lis
blue yarn	Samson
red tracer yarn	New England

3.1.4.6 Synthetic Rope Strength.

a. The rope manufacturer should be consulted for the breaking strength or the safe working load. If the breaking strength is quoted, the appropriate factor of safety should be used to determine the safe working load. The advertised rope strength is based on statistically determined averages. Very few manufacturers publish minimum breaking strength data. The minimum breaking strength is determined by taking two standard deviations below the mean value of a statistically significant number of individual tests.

b. Winch line applications require a rope that exhibits low to moderate elastic elongation characteristics. Synthetic ropes are advertised as non-conductive and are therefore attractive for use around energized wires or electrical components. The quoted dielectric properties are for clean new ropes. The presence of dirt, grease, humidity, and entrained moisture can alter those dielectric properties causing the rope to be conductive. This can cause serious injury or death if personnel contact an electrically charged rope or winch components.

c. Typical synthetic materials used for winch lines is an all polyester, polyester/Spectra, or Dyneema double braid construction. This type of rope exhibits high strength, low elongation, and excellent abrasion resistance. Composite nylon and polyester ropes are also commonly used. These materials are used together to take advantage of the combined strength of both fibers while reducing the elongation compared to an all nylon construction. Composite ropes of Spectra or Dyneema and polyester consist of an inner braided core of spectra and an outer braided jacket of polyester.

d. Spectra is similar to Dyneema fiber, but is not as strong or as durable. Because of its strength and durability Dyneema is the premier synthetic fiber for winching applications. There are multiple different types of Dyneema fiber. Regardless of the fiber, all winch lines are braided in a 12 strand construction. Each strand is composed of many fibers and 12 strands are woven together to form the rope.

e. As part of the manufacturing process most synthetic ropes are pre-stretched. This reduces or eliminates the break-in process and helps to limit the amount of elastic elongation and improve rope strength. Pre-stretching involves the application of heat during the process and is sometimes known as heat-setting. Consult the rope manufacturer to determine if a break-in is required and whether there is a specific procedure.

f. The initial loading will result in some elastic rope extension. This is immediate upon loading and is immediately recoverable when the load is released. After the elastic extension of the initial loading, the rope will experience what is known as viscoelastic extension. This is an additional change in length over time. Unlike elastic stretch, viscoelastic stretch will recover slowly over time after the load is released. With continued use the rope will experience creep. Creep is a permanent, non-recoverable change in length and is time and load dependent. Once the load is released and elastic and viscoelastic extension recovered, the rope will have experienced an element of permanent elongation. This is a factor of creep and break-in where the individual fiber components in the rope and splice settle into their preferred position while under load. The rope length should be measured prior to the start of test and at intervals during a winch durability test. Measurements should be taken with similar preload (typically 10 percent of the rating) to ensure an accurate of the rope elongation. The length measurements can be sensitive to the time and rope duty cycle.

3.1.4.7 Synthetic Rope Inspection.

a. Winches with a brake inside the winch drum create significant heat during operation. The critical temperature of most synthetic winch rope is around 66 °C (150 °F). Degradation of the rope fibers and a loss of strength is affected by excessive heat.

b. Inspect the fairlead, hawse, or pulley blocks closely. If steel cable has run through them, it is possible there are cuts, scrapes, burrs, or other sharp areas that require attention. Inspect the rope path for sharp edges and potential rub points. Any condition harmful to the rope in use at the time should be corrected. If a roller fairlead is used, make sure the rollers are free.

3.2 Test Controls.

a. Design and proof loads of the towbar and associated hardware require validation prior to field testing. The validation process includes tensile machine testing and field testing. A more detailed description of the towbar validation process is described in the Tow Bar Test Plan[16].

b. All safety Standard Operating Procedures (SOPs) shall be observed throughout test operations.

c. Using the material properties of the towbar and associated components, calculate the maximum allowable strain based on the yield stress. If the values are exceeded at any point in the test, the towbar should be removed from service.

d. Modified tow pintles and their mounting hardware should be clearly marked as test assets and removed from service when tests are completed.

e. Correct levels of lubricant, hydraulic fluid, coolant, etc. should be maintained throughout the tests for the towing and recovery vehicle.

f. Vehicles will be operated until their normal operating temperatures are reached before initiating each test.

g. Critical fluid temperatures should be monitored during the test. The high loads placed on the drive train from towing and recovery operations could potentially result in overheating of components.

3.3 Factors of Safety.

a. Multiple references were consulted and there was a wide discrepancy in the recommended factors of safety for individual towing and recovery devices. Sources and recommendations are presented in the following paragraphs. The vehicle specification should also be reviewed to determine if any guidance is provided.

b. Structural adequacy and mounting of towbars information is provided in FMCSR 393.71. Every towbar shall be structurally adequate and properly installed and maintained. The required strength of towbars for towed vehicles of 5,000 pounds and over gross weight shall be computed by means of Equations 3 and 4.

$$\text{Longitudinal strength} = \text{gross weight of towed vehicle} \times 1.3 \qquad \textit{Equation 3}$$

$$\text{Strength as a beam} = \text{gross weight of towed vehicle} \times 0.6 \qquad \textit{Equation 4}$$

c. Because of the extreme operational environments and expectations for the military towbar, the commercial structural adequacy provided by FMCSR 393.71 was not considered sufficient. The longitudinal strength and strength as a beam factors were increased to a minimum of 1.5. The application definitions presented in Table 3 are provided from the Machinery's Handbook[17], and better define a realistic factor of safety when individual guidance is not provided.

TABLE 3. CONSIDERATIONS FOR STRUCTURAL ADEQUACY

FACTOR OF SAFETY	APPLICATION DEFINITION
1.3 – 1.5	For use with highly reliable materials where loading and environmental conditions are not severe, *and*, where weight is an important consideration.
1.5 – 2.0	For applications using reliable materials where loading and environmental conditions are not severe.
2.0 – 2.5	For use with ordinary materials where loading and environmental conditions are not severe.
2.5 – 3.0	For less tried and for brittle materials where loading and environmental conditions are not severe.
3.0 – 4.0	For applications in which material properties are not reliable and where loading and environmental conditions are not severe, *or*, where reliable materials are to be used under difficult loading and environmental conditions.

d. To ensure safe operations in service, the actual load on a rope should only be a fraction of the breaking load. To account for all of the stress placed on a rope in hoisting or winching operations, and to provide a margin of strength necessary to safely handle loads and guard against accidents, the rope must have a factor of safety.

e. For rigging ropes, the minimum acceptable factor of safety is 5:1. The factor of safety for live or running ropes that wind on drums or pass over sheaves shall be not less than 3.5:1. The factor of safety for standing or guy ropes shall be not less than 3:1. The factor of safety is often considered as reserve strength and is used for additional capacity. This is unacceptable and considered bad design practice.

f. TOP 02-2-712 Automotive Winches[18] provides the following recommendation for the appropriate factor of safety. Check the winch cable to ensure that the proper diameter is being used to safely handle the loads specified for the winch. The ratio by which the rated breaking strength of the cable should exceed the capacity of the winch is the safety factor. This safety factor should be determined and compared to the prescribed safety factor before any loads are applied to the cable. In lieu of guidance, the cable should have a minimum safety factor of 2: 1.

g. The factor of safety accounts for:

(1) Reduced capacity of the rope below its' breaking strength due to wear, corrosion, abuse, and variations in size and quality.

(2) End fittings and anchors that are not as strong as the rope.

(3) Loads imposed by acceleration, deceleration, and inertia (starting, stopping, swinging, and jerking of the load).

(4) Increase in line pull due to friction of the rope passing over sheaves.

(5) Inaccuracies of the load and rigging.

(6) Reduced strength due to bending over sheaves and drums (fatigue).

h. When information is not available, as a rule of thumb, the working load limit can be estimated by squaring the diameter of wire rope in inches, and multiply by 8 to obtain an estimated working load limit in tons (FM 20-22[19]).

4. TEST PROCEDURES.

4.1 Towing Tests.

4.1.1 Towing Compatibility.

Towing compatibility tests are conducted for like and recovery specific vehicles for all of the towed vehicle configurations. Safety and performance limitations are documented. TOPs covering the individual performance metrics are presented below. Refer to each referenced TOP for details.

a. Physical Characteristics (TOP 02-2-500). Characteristics that define each towing configuration should be measured. The pintle and towing connection points should be referenced to a fixed origin on the vehicle. If the center of gravity is known it should be used as the reference. Other possible reference locations are axle centerlines, ground plane, and the vehicles' longitudinal centerline.

(1) If the towed vehicle is damaged, its' condition should be carefully documented. Flat tires, damaged suspension, and missing components should be photographed and their impact to the vehicle attitude measured.

(2) The functionality of the towbar, safety chains, inter-vehicular electrical cable, and the airlines will be verified. The physical characteristics of the towbar should be completed using TOP 02-2-606 as a guide.

b. Weight Distribution (TOP 02-2-801). Sequential weights by axle or roadwheel station will be determined. Measurements should be taken for the towing vehicle and each towed combination. The tire, wheel, and axle load limits should be recorded. Data are typically recorded from the tire sidewall, wheels, and the vehicle data plate. The axle manufacturer and model are needed to define the axle weight rating.

c. Center of Gravity (TOP 02-2-800). Ideally, the center of gravity would be measured in 3 planes by an appropriate method outlined in the TOP. The lateral and longitudinal center of gravity locations can be calculated using the weight distribution data and the appropriate physical characteristics.

d. Steering and Handling (TOP 02-2-718[20]). Each towed combination will perform ten figure-8 turns, and 90-degree full left and full right turns checking for interference of the combination. All chains and cables will be verified for adequate length. The minimum curb-to-curb, wall-to-wall, and turn circle inner diameter will be measured for the each towing combination to calculate a minimum intersection width. The test should be repeated with the towed vehicle only.

e. Acceleration; Maximum and Minimum Speed (TOP 02-2-602 w/CN1[21]). Each combination should be operated at constant ground speeds consistent with the road surface (paved or gravel), recommended towing speeds, and the mission profile to evaluate the towed load tracking. Multiple speed intervals should be selected covering the speed range of the combination. Each combination will be towed in a straight line and the deviation of the towed vehicle's path from that of the towing vehicle will be measured. Simple road marking methods may be employed such as chalk marking or water trail when the GPS is not available or the accuracy is not sufficient. The Federal Motor Carrier Safety Regulation criteria will be used to determine conformance.

f. Braking (TOP 02-2-608[22]). Brake effectiveness tests should be conducted at 16.1 km/hr (10 mph) intervals up to the safe towing speed. Deceleration should be used as the test control for each brake stop. Road speed, stopping distance, and pedal effort should be recorded. Special attention should be given to the required driver inputs (braking and corrective steer) and the towing/towed vehicle reaction. Tests should be conducted on level paved and gravel road surfaces.

(1) Grade holding ability should be verified for each towed combination. Towing/recovery operations on longitudinal grades above 30 percent are not conducted unless a specific design or operational criteria are provided. Brake holding tests should be conducted initially in the ascending direction. Each combination should be maneuvered onto the grade, the minimum distance needed to have the combination wheelbase on the same plane. When conducting tests in the descending direction, the combination should be backed up the grade, if possible.

(2) If the vehicles must descend from the top of a grade, traffic cones should be used to give the driver a visual means of alignment with the grade so that initial on-grade steering corrections can be eliminated. Speeds should be kept to the minimum required to negotiate the grade. When operating on grades above 15 percent, the operator must anticipate the increased loads and exaggerated vehicle reactions while attempting to control the combination. The operator should provide minimal throttle until the load begins to push them down the grade. Once the load begins to push the combination, the operator should move forward a small amount, then bring the combination to a stop again, and wait for all momentum to stop before moving forward another small amount. Continue to make small advances down the grade until comfortable that the load can be stopped or the vehicle slides down. No steering corrections should be made while a tracked vehicle is attempting a brake stop event on the grade. If a steering correction needs to be made, the vehicle needs to be moving.

g. Standard Obstacles (TOP 02-2-611[23]). Obstacles that define the performance criteria of the individual vehicles should be attempted. Attention should be given to towbar clearance or interference, towed vehicle traction and power.

h. Gradeability and Side Slope Operations (TOP 02-2-610[24]). Longitudinal slope operations are conducted concurrent with the brake holding and controllability tests. Side slope operations are typically limited to 30 percent with wheeled vehicles and 40 percent with tracked and tactical vehicles. Multiple passes on each side slope should be made while gradually increasing the amplitude of the sine wave path.

4.1.2 Additional Performance Tests for Towing Evaluations.

Additional performance tests may be required for the towing vehicle. Dedicated recovery vehicles may have higher capacity cooling systems, higher numerical axle ratios, different transmission shift schedules, parasitic loads from power take-offs, pumps, and generators that will require characterization.

a. Drawbar Pull (TOP 02-02-604 w/CN1[25]). Drawbar pull/tractive effort test data are used to determine the reserve pull and power available at the pintle. Tests are typically conducted in the lower gears not to exceed 20 mph. Data are used to predict gradeability limits and off road performance estimates.

b. Resistance to Towing (TOP 02-2-605[26]). Resistance to towing tests are used to measure the aggregate motion resistance of the towing vehicle and towed loads independently, as a function of towing speed and terrain. Tests are conducted on uniform level surfaces. Paved and gravel are the primary road surfaces. Off road towing resistance tests require additional test controls. Characterization of the test site to include soil type, soil strength profile, moisture content, vehicle sinkage are measured. Refer to TOP 02-02-619A for details.

c. Full load cooling (TOP 02-2-607[27]). Cooling tests for the towing vehicle are conducted on a level paved test course using a mobile field dynamometer for control. Constant resistive loading is applied for sufficient time periods to characterize the temperatures of the powertrain lubricants and coolant. Specific loading conditions matching the vehicle specifications are selected. Continuous grade operations are simulated using measured vehicle weights, motion resistance, and the required gradient. In the absence of specific criteria, the maximum torque and power operating states of the engine should be tested. Select the appropriate lowest gear that minimizes or eliminates wheel or track slip. The load and speed condition that provides the lowest torque converter speed ratio should be determined and tested.

d. Loading representing the towed load motion resistance at the upper paved towing speed limit should be checked. This condition is completed without the dynamometer. The actual towed load is towed to provide the required motion resistance. Towed operations are conducted for sufficient time periods to characterize the temperatures of the powertrain lubricants and coolant.

e. Downhill Brake Performance/Brake Fade.

(1) Wheeled towing vehicles brake fade tests should be conducted using the appropriate fade schedule presented in TOP 02-2-608. The fade schedules are delineated based on vehicle weight. A minimum of five fade runs should be conducted for each towing configuration. Run-to-run consistency (or lack thereof), and a comparison to the cold stopping performance are of particular interest.

(2) Additional fade tests are recommended using lower gearing combinations, altered speed intervals, and deceleration and auxiliary brake devices, if equipped, to better shape the operational driving techniques.

(3) Tracked vehicles use the International Test Operations Procedure (ITOP) 02-2-627(1)[28] to evaluate repetitive braking and hot stopping performance.

4.1.3 Towing Endurance Tests.

a. Upon completion of the towing compatibility tests, each towing configuration should be operated over its' representative mission profile. For like-vehicle towing, a minimum of fifty miles, weighted to represent the mission profile, should be used. The towed load should be representative of the weight class. Additional payload may be added to simulate the increased motion resistance from battle damage.

b. The operational and organizational concepts must be considered when developing an appropriate endurance testing profile for recovery specific missions. System capabilities, rationale, and mission profiles are explained.

c. The mission profile is typically broken down by individual mission functions and annual usage by geographical area. Recovery functions are presented in hours, number of expected recoveries, percentage of time towing, expected operational ground speed, area of operational movement, and maintenance shop support. Towing percentages can be as much as 70 percent of the operational mission for recovery specific designs.

4.2 Recovery Specific Tests.

Most recovery operations are accomplished with winches. There are two basic types of winches; constant pull capacity winches, and variable pull capacity winches. The recovery systems consist of winches, fixed or movable booms, cranes, and rigging. The testing of chains and rigging are not included in this document. The tester must ensure that accepted rigging techniques are being followed and appropriate hardware are used. If intentional exceptions are made, they need to be fully documented and the appropriate safety precautions need to be developed and followed.

4.2.1 Winch Performance and Safety.

a. Prior to any endurance recovery operations the winch performance and safety should be evaluated. The specific procedures are provided in TOP 02-2-712. Winch related safety and performance criteria are presented in paragraph 2.2.2 Recovery Devices. Characterization and inspection of wire winch/hoist ropes are presented in paragraph 3.1.3. Characterization and inspection of synthetic winch/hoist ropes are presented in paragraph 3.1.4. The following observations and tests are the minimum recommended to evaluate winch performance and safety. Additional performance tests are presented in TOP 02-2-712 and SAE J706.

b. Controls for the winch must provide the operator with convenient and safe winch operation.

c. Adequate guards or shields must be provided to protect the operator should a cable fail, particularly when the controls are located near the winch. Moving parts that may become a hazard to operating personnel should be fully enclosed or properly guarded.

d. The cable must be of a size and type that will provide an adequate factor of safety along with sheaves, rigging, and other winch-related items. Refer to paragraph 3.3 for recommendations on the acceptable factor of safety for winching and recovery systems.

e. The winch capacity and brake holding ability should be determined using paragraph 4.2 of TOP 02-2-712. Winch overload protection devices are characteristically inaccurate and may impose loads in excess of the rated capacity on the winch. An overload test should be conducted in accordance with paragraph 4.2.1 of TOP 02-2-712.

f. All hazards shall be categorized in accordance with Military Standard (MIL-STD)-882E[29].

4.2.2 Winch Endurance.

a. Endurance tests of winches are designed according to the intended application of the winch. Tests consist of repetitive winch operations for a prescribed number of test cycles and/or operating time in the manner described for the particular winch type. During these tests, a test cycle is not started when it is obvious that overheating of the winch system would occur before completion of the cycle.

b. Refer to TOP 02-2-712 for the recommended number of cycles required, and loading conditions.

c. The advertised winch duty cycle ratings will be different than those conducted using the TOP endurance test methods. The winch duty cycle rating as described in SAE J706 is conducted at one half the rated load.

d. When planning recovery tests and reviewing performance test specifications, make sure that all parties understand the difference in the requirements. A winch system with a significantly higher advertised rating may be required to meet the actual test requirement.

4.2.3 Determination of Winch Rating.

a. There are two definitions of winch rating. The primary definition comes from requirements derived from the operational mission profile and is demonstrated by the appropriate winch endurance duty cycle specified in TOP 02-2-712.

b. A second definition is provided in Surface Vehicle Standard SAE J706 Rating of Winches. The rated load is defined in SAE J706 as the load that produces the maximum rated line pull on the first layer. This SAE Standard applies only to new winches that are primarily designed for intermittent pulls and lifts and whose configuration and condition are the same as when they were shipped by the manufacturer. They are not intended to be used in any manner for the movement of personnel. The maximum rated line pull is determined using the following method.

c. A load equal to twice the desired maximum rated line pull will be applied to the drum on the first layer at an effective distance from one flange of no more than five times the maximum recommended wire rope diameter. The load will be maintained while the winch is powered for at least one drum revolution at half of the rated line speed. The direction of pull will be on a horizontal within ± 15 degrees and perpendicular to the centerline of the winch drum within ± 5 degrees. The test will then be repeated with a load equal to the desired rated line pull. Both tests will then be repeated on the opposite end of the drum.

4.2.4 Boom/Crane Stability.

a. Surface Vehicle Standard SAE J765 Crane Load Stability Test Code[30] and Surface Vehicle Recommended Practice SAE J1289 Mobile Crane Stability Ratings[31] are used to determine the installed boom or crane stability.

b. The purpose of this test is to determine the maximum capacity of a crane to counterbalance loads applied on its hook block. The capacity of the crane is reported in terms of the load in kilograms (pounds) and its corresponding radius in meters (feet) for a specified position of the upper structure with respect to the mounting. A capacity curve is developed using the load and boom radius data.

c. Stability calculations are to be carried out in those positions or configurations for which stability is at a minimum. If different ratings are to be specified for different working areas, calculations shall be made to check stability for each published working area.

d. Equation 5 (from SAE J1289) shall be used to establish stability based rated loads.

$$P \leq T - 0.1F/1.25 \qquad \textit{Equation 5}$$

where:

0.1 and 1.25 are constants and dimensionless.
P = rated load.
T = tipping load (using the procedures and definitions of SAE J765).
F = load factor assumed to act at either main boom point (F_b) or jib point (F_j).

4.2.5 Lift and Carry.

Lift and carry operations should be performed only after the stability ratings are established. Load and distance requirements are generally specific to the individual test platform. The operational requirements document or system specification should be consulted to develop the specific test design. Payload, distance travelled, and operating environment are usually defined.

4.2.6 Functional Tests of System Components.

Recovery specific tasks should be demonstrated once any performance or safety limitations are determined. Procedures specific to the recovery vehicle design should be followed. Test include but are not limited to:

a. Simultaneous recovery operations (recover overturned vehicle).

b. Simulated battlefield recovery and vehicle maintenance.

c. Setup and operation of vehicle outriggers or stability enhancements.

d. Spade/anchor operations.

e. Use of hydraulic/pneumatic recovery specific tools.

5. DATA REQUIRED.

5.1 Towing Tests.

5.1.1 Towing Compatibility.

a. The results of the towing compatibility tests are used to define any operational and performance limitations for each towing configuration. Test results should be compared to the baseline data determined for the towed vehicle, by itself. Data should also be compared by operational terrain. Changes in driving techniques may be needed to operate safely off road compared to secondary road or paved operations. Additional tests may be needed to further define the towing performance.

b. Front and rear overhang, approach and departure angles, overall length, width, height, and ground clearance profiles are required measurements. All measurements should be completed on the individual vehicles and on the towing combination for each vehicle configuration. The pintle and towing connection points should be referenced to a fixed origin on the vehicle. If the center of gravity is known, it should be used as the reference. Other possible reference locations are axle centerlines, ground plane, and the vehicles' longitudinal centerline.

c. Documentation of interference or clearance issues from the towbar, safety chains, electrical, or brake connections are captured with photographs.

d. Weight distribution, by wheel station should be determined for the towing vehicle and each complete towed configuration. A comparison by individual wheel position should be completed to quantify any increased and/or overloading of axles, tires, or wheels as a result of the towed load. Components may be overload for short durations and speeds and tire pressures may be adjusted to account for the overload. The tire, wheel, and axle manufacturer should be consulted in these instances. Refer to the Tire and Rim Handbook[32] for recommendations for terrain, speed, and inflation pressure changes as a function of the tire loading.

e. The curb-to-curb, wall-to-wall, and turning circle inner diameter are measured for each towed configuration. Interference that limits the turning ability of the combination will be documented. The minimum intersection width will be calculated from the turning diameter data.

f. Continuous time-velocity data are required for the towing vehicle and each towed configuration. Times to specific ground speeds are determined from the time-velocity data. Additional data including engine speed, torque converter lockup status, accessory loads, cooling fan status, and gear selected and obtained may be needed to completely define the towing performance. If a reduction in performance is noted, speed limits should be recommended to preserve the powertrain performance and/or high speed vehicle controllability.

g. The brake effectiveness data are used to determine whether speed and/or terrain limitations are needed when towing. Data required to present the brake effectiveness are road speed, stopping distance, and deceleration. Friction material temperature is required as a test control. The individual brake events are typically initiated below a specific temperature insuring the results are not affected by brake fade. Brake fade tests characteristics are determined using the weight specific test schedule outlined in TOP 02-2-608. Subjective data including required steering corrections, wheel lockup, and driving lane departure are noted for each stop.

h. The brake holding ability on longitudinal grades are presented as the maximum grade on which the towed combination can be stopped and controlled using normal pedal force for each direction of travel. The performance over each defined obstacle is explained. Typical failures or reductions in performance include loss of traction, insufficient power, or towbar interference. The standard obstacle and gradeability data are used for comparative performance and possible terrain limitations while towing.

5.1.2 Additional Performance Tests for Towing Evaluations.

The individual performance TOP/ITOP should be consulted for data required.

a. Drawbar Pull (TOP 02-2-604 w/CN1).

b. Resistance to Towing (TOP 02-2-605).

c. Full Load Cooling (TOP 02-2-607).

d. Braking - Wheeled Vehicles (TOP 02-2-608).

e. Brake Fade (Tracked Vehicles) (ITOP 02-2-627(1)).

5.1.3 Towing Endurance Tests.

a. The total number of hours and the distance towed for each terrain type are tracked for each towing configuration.

b. The results of the towbar, pintle, and towing eye inspections are presented for regular inspection intervals. Component wear is quantified by physical measurements and photo documentation.

c. Changes to driving techniques for specific terrains can be quantified by developing histograms of vehicle performance metrics to include vehicle speed, time in specific gears, torque converter lockup status, and powertrain temperatures for the different towing configurations and the towing vehicle by itself.

d. If the endurance tests are conducted over long time periods, or where there are significant changes to the test course conditions, the conditions must be documented and accounted for in the analysis.

5.2 Recovery Specific Tests.

5.2.1 Winch Performance and Safety.

a. The results from the winch cable and hardware inspections are required. Any degradation of the winch rope should be compared to the specific standard and documented with photographs.

b. Cable load measurement should be acquired at a minimum sample rate of 100 Hertz (Hz) to capture the operation of the safety overload device. Winch motor current and voltage are measured for electrically driven winch systems, and pressure and temperature are required for hydraulic systems.

c. If adjustments are required to the control system they should be explained in a narrative with all supporting engineering data.

d. All tests should be captured with real-time digital video. High-speed video may be required to capture winch rope behavior.

5.2.2 Winch Endurance.

a. The cable loading, line speed, and winch specific temperatures are recorded versus time during winch endurance testing. Depending on the type of recovery system (e.g., self-recovery front-mounted, boom hoist winch, crane winch), follow the operating conditions outlined in paragraph 4.5 of TOP 02-2-712.

b. The SAE J706 duty cycle rating is established by continuously raising and lowering a load equal to or greater than 1/2 rated load, at rated line speed, without stopping at the top and bottom of each lift any longer than necessary to reverse direction. The test begins when the lubricating oil temperature reaches 38 °C and terminates when the oil temperature either reaches 121 °C or stabilizes below 121 °C. The duty cycle rating is the total distance (meters) of travel, both up and down, between 38 °C and 121 °C, or, if the temperature stabilizes below 121 °C, the duty cycle rating is the stabilization temperature. The oil used in the test will be the same kind and quantity that is recommended or normally furnished with the winch.

5.2.3 Determination of Winch Rating.

a. There are two methods for determining the winch rating. Depending on the type of recovery system (e.g., self-recovery front-mounted, boom hoist winch, crane winch), follow the operating conditions outlined in paragraph 4.5 of TOP 02-2-712.

b. For each test, record the applied line loads (and pressures for hydraulic winches, motor current, and voltage for electric winches), time duration, engine speed, and gear case hydraulic oil or motor temperatures. At test completion, conduct a physical inspection of the winch drum, cable, and rigging hardware.

c. Determination of the winch rating using SAE J706 may require modifications to the overload protection system and the rope. In order to obtain sufficient wire rope strength to lift twice the desired maximum rated load, the rope may be oversized, or multiple wire ropes may be used, or both. If wire rope of a size other than the maximum recommended size is used, rated line pull must be calculated per Equation 6.

$$Q = Pr/t$$ *Equation 6*

where:

P = rated line pull (pounds).
Q = test load (pounds).
t = radius to center of test load rope from centerline of drum (inches).
r = radius to center of first layer of maximum recommended wire rope size from centerline of drum (inches).

5.2.4 Boom/Crane Stability.

Where it is desired to determine the balance point capacity of a crane throughout a range of loads or radii, follow the procedures as outlined for individual determinations. This includes making sure that load and radius are determined for each extreme of the range and at a sufficient number of intermediate points to permit plotting a curve. Plot a curve showing the maximum capacity of the crane with the load in kilograms (pounds) as ordinate and radii in meters (feet) as abscissa. Use a representative number of boom lengths for a given capacity chart.

5.2.5 Lift and Carry.

a. The hook load and distance travelled will be documented. The site should be described in detail. If the operations are conducted on paved then only the pad gradient needs to be defined. Even small grades, which are often required for drainage, can have a significant impact on the vehicle stability, when operating near its limit. If a grade is determined, then the direction of travel while on the grade should be described.

b. Gravel or off-road surfaces require additional documentation. The bulk density, moisture content, and compaction (soil strength) should be provided. The soil type as defined in TOP 02-2-619A should be included.

c. All lift and carry operations should be captured with real-time digital video.

6. PRESENTATION OF DATA.

6.1 Towing Tests.

6.1.1 Towing Compatibility.

a. Record the vehicle inspection data on a report form, appropriate to the vehicle (e.g., DA Form 2404). The overarching objectives of the towing compatibility tests are to define any speed, terrain, or towing configuration combinations that would limit the operation of the vehicles.

b. Physical characteristics are presented in tables comparing the towing vehicle to the towed vehicle and towed load configurations. Weight distribution data should be presented in tables. Metrics that specifically impact highway transport (e.g., height and axle weight) should be compared to the appropriate standard. Weight data should be compared to tire, wheel, and axle ratings. Any adjustments to tire pressure, operating speeds, or recommended terrain that mitigate an overload condition should be discussed. Characteristic photographs should be taken to capture overall views of the vehicle(s) and the towbar connections.

c. The curb-to-curb, wall-to-wall, turning circle inner diameter, and calculated intersection width should be presented in a table comparing each towed configuration with the towing vehicle. Any reduction in performance should be discussed in the narrative. Any potential interference should be photographed.

d. Time-velocity data should be presented in a table and in graphic form for each towed configuration and the towing vehicle. The table should present the times to specific road speed intervals, the maximum speed obtained, and the time to reach the maximum speed. The maximum speed limit should be explained for each configuration. Determine whether the maximum speed was limited by the engine controls (e.g., governor or Electronic Control Module (ECM)), or the available engine power. Each graphic should include the following at a minimum in the legend.

(1) Test site.

(2) Vehicle test weight(s).

(3) Fuel type.

(4) Date(s) of test.

e. Brake effectiveness data are presented graphically, plotting the brake apply pressure on the abscissa and the stopping distance or deceleration on the ordinate. The data are presented for a constant initial road speed target. Variations in the target speed, and the resulting effect on the stopping distance, are corrected using the procedure outlined in SAE J46[33]. Conditions that require steering corrections or create wheel lockup should be noted in the graphic. Hot stop performance determined from the separate fade tests are plotted on the appropriate effectiveness curve to highlight any degraded performance.

f. The longitudinal slope performance is presented graphically. Data included are the towing configuration, direction of travel (ascending or descending), and whether the test was successful. For unsuccessful tests, the limitation should be spelled out in a remarks column. Typical failures or reductions in performance include loss of traction, insufficient power, or towbar interference.

6.1.2 Towing Endurance Tests.

a. Changes to driving techniques for specific terrains are quantified using histograms of vehicle performance metrics to include vehicle speed, time in specific gears, torque converter lockup status, and powertrain temperatures for the different towing configurations and the towing vehicle by itself.

b. If the endurance tests are conducted over long time periods, or where there are significant changes to the test course conditions, those conditions must be documented and accounted for in the analysis.

6.2 Recovery Specific Tests.

6.2.1 Winch Performance and Safety.

a. The results from the winch cable and hardware inspections are presented in a narrative. A narrative describing the rope history should include type of tests performed (e.g., stall pulls, brake check, 50 percent line speed, etc.), the number of pulls, and the total time under load. Any degradation of the winch rope should be compared to the specific standard and documented with photographs.

b. Any adjustments to the control system should be explained in the narrative with a summary of the supporting engineering data.

6.2.2 Winch Endurance.

a. The cable loading, line speed, and winch specific temperatures are recorded versus time for the winch endurance test. Data can be presented in graphic form versus time for the cable load and component temperatures. Data can also be summarized in tabular form for the line speed data and presented for each wrap of the drum.

b. The SAE J706 duty cycle rating is presented as the total distance of travel, both up and down, between 31 °C and 121 °C, or, if the temperature stabilizes below 121 °C, the duty cycle rating is the stabilization temperature.

6.2.3 Determination of Winch Rating.

a. The winch rating, as determined from TOP 02-2-712, is presented as the average cable loading used to successfully complete the endurance test. A narrative will typically be required explaining how the final load was achieved and/or the limitations imposed on the operation.

b. The applied line loads (and pressures for hydraulic winches, motor current, and voltage for electric winches), time duration, engine speed, and gear case hydraulic oil or motor temperatures are presented in tabular form for each test. A range of operation may be required for those parameters that show variation during operation. Starting and ending temperatures are also presented.

c. Determination of the winch rating using SAE J706 may require modifications to the overload protection system and/or the rope. Changes to the recovery system will be discussed in a narrative and documented with photographs.

6.2.4 Boom/Crane Stability.

Data are plotted showing the maximum capacity of the crane with the load in kilograms (pounds) as ordinate, and radii in meters (feet) as abscissa. The position of the boom relative to the vehicle will be noted on each graph.

6.2.5 Lift and Carry.

a. The load and distance travelled are documented with real time digital video. The site should be described in a narrative. For paved operation, the pad gradient need and direction of travel on the pad are presented. Even small grades can have a dramatic effect on the vehicle stability.

b. Gravel and off-road surfaces require additional documentation. The Unified Soil Classification System (USCS) soil type, bulk density, moisture content, and compaction (soil strength) are tabulated.

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APPENDIX A. ABBREVIATIONS.

°C	degrees Celsius
°F	degrees Fahrenheit
AKERR	Allied Kinetic Energy Recovery Rope
ATEC	U.S. Army Test and Evaluation Command
BDAR/R	Battle Damage Assessment and Repair/Recovery
BII	Basic Issue Item
CFR	Code of Federal Regulations
cm	centimeter
CTIS	Central Tire Inflation System
DA	Department of the Army
ECM	electronic control module
FM	Field Manual
FMCSR	Federal Motor Carrier Safety Regulation
ft	feet/foot
GAWR	Gross Axle Weight Rating
GCWR	Gross Combination Weight Rating
GPS	Global Positioning System
HMPE	High Modulus Polyethylene
Hz	Hertz
in.	inch
ISO	International Organization for Standardization
ITOP	International Test Operations Procedure
kg	kilogram
km/hr	kilometers per hour
lb	pound
m	meter
MIL-STD	Military Standard
mm	millimeter
mph	miles per hour
NIST	National Institute of Standards and Technology

APPENDIX A. ABBREVIATIONS.

RVR	Recovery Vehicle Rating
SAE	Society of Automotive Engineers
SOP	Standard Operating Procedure
TOP	Test Operations Procedure
TRADOC	U.S. Army Training and Doctrine Command
USCS	Unified Soil Classification System
UV	ultraviolet

APPENDIX B. DEFINITIONS.

Term	Definition
Aramid	A high strength, high modulus fiber. Trade names include Kevlar and Twaron.
Breaking Strength	The greatest stress that a material is capable of withstanding without rupture (TM 3-34.86).
Dacron	duPont trade name for polyester.
Dyneema	Dutch State Mines trade name for HMPE fiber.
Fleet Angle	The angle between a line drawn from the center of the sheave or fairlead edge through one flange of the drum and a line through the center of the sheave. In some installations the fleet angle may be different, left and right.
Freeboard	The amount of drum flange that extends radially past the top wire rope layer of a full drum (SAE J706).
Free Spool	The operation of unspooling wire rope from a drum by pulling on the free end of the rope while the winch is stationary. The drum is disconnected (declutched) from its powertrain during this operation (SAE J706).
Full Drum	A drum containing the maximum permissible number of layers as defined in Equation 7 (SAE J706).

$$L = F - D - 2m/2d \qquad \textit{Equation 7}$$

where:

L = maximum permissible number of layers.
F = drum flange diameter (inches).
D = drum Barrel diameter (inches).
d = wire rope diameter (inches).
m = freeboard $\geq$0.7d (inches).

Term	Definition
HMPE	High Modulus Polyethylene, a high strength, high modulus fiber. Trade names include Dyneema and Spectra.
Kevlar	duPont trade name for aramid.

APPENDIX B. DEFINITIONS.

Term	Definition
Lang lay	Strands and wires are wound in the same direction. Because of the greater length of exposed wires, Lang lay provides greater abrasion resistance of wires and less radial pressure on small diameter sheaves or drums. Disadvantages of Lang lay rope are the tendency to kink or open up between strands making it undesirable for use where dirt and moisture are present (TM 3-34.86).
Lay	The direction of winding of wires in a strand and strands in rope. The wires and strands may be wound in the same direction or in opposite directions (TM 3-34.86).
Layer	All wraps of the same diameter between drum flanges (SAE J706).
Mire Factor	Multiplier used in the field calculation of the total load resistance required for a recovery operation. Mire factors (Recovery Smartbook[33]) are defined in Table B-1.

TABLE B-1. MIRE FACTORS

MIRE FACTOR	WHEELED VEHICLE	TRACKED VEHICLE
1	Up to the center of the wheel hub.	Up to the top of the road wheel.
2	Over the center of the wheel hub to top of the fender, but not over the fender.	Over the top of the road wheel to the fender, but not over the fender.
3	Over the fender.	Over the fender.

Term	Definition
Monofilament	A fiber having relatively large diameter.
Multifilament	A fiber having relatively small diameter.
PA	Chemical abbreviation for polyamide or nylon.
PE	Chemical abbreviation for polyethylene.
PES, PET	Chemical abbreviations for polyester.
PP	Chemical abbreviation for polypropylene.
PPTA	Chemical abbreviation for aramid.
Polyamide	The common chemical name for nylon.

APPENDIX B. DEFINITIONS.

Term	Definition
Polyolefin	The chemical group that includes both polypropylene and polyethylene.
Rated Line Pull	The rated line pull is the line pull on any layer that results from the output torque that produces maximum rated line pull on the first layer (SAE J706).
Rated Load	The load that produces the maximum rated line pull on the first layer (SAE J706).
Recovery	The process of freeing or retrieving immobile, inoperative, or abandoned equipment from its current position and returning it to service or to a maintenance site for repairs. These actions typically involve extracting, towing, lifting, or winching (Recovery Smartbook).
Recovery Equipment Boom Rating	The basic performance rating of the recovery equipment is the static weight the equipment can lift at a specified boom length, when the boom is elevated at an angle of 30 degrees above horizontal. If lifting is done by winching, load lines must be vertical and the lifting cables should share the load equally, measured with a live (weight) or load cell. The specified boom length is the length of the boom when measured parallel to the boom structure, from the centerline of the boom pivot, (heel) to the centerline of the wire rope (SAE J 2512).
Reduction Factor	The reduction in total load resistance accounting for specific recovery scenarios (Recovery Smartbook). Scenario 1 (10%): Recovery in the opposite direction from which the mired vehicle was traveling. Scenario 2 (40%): Application of power to the tracks of the mired vehicle. Scenario 3 (50%): Combination of recovery in the opposite direction and applying power to the tracks of the mired vehicle.
Regular lay	Strands and wires are wound in opposite directions. The most common is right regular lay (strands wound right, wires wound left) (TM 3-34.86).

APPENDIX B. DEFINITIONS.

Term	Definition
Resistance	Restraining forces contributed to the load (SAE J2512).
Reverse lay	The wires of any strand are wound in the opposite direction of the wires in adjacent strands. Reverse lay is not typically used in winch and recovery systems (TM 3-34.86).
Rigging	The process of assembling recovery equipment, and tackle systems to multiply the available force to overcome total resistance (Recovery Smartbook).
Recovery Vehicle Rating (RVR)	Manufacturer's rated capacity of recovery vehicle (SAE J2512).
Safe Working Load	The maximum load that can safely be applied to a particular type of rope (TM 3-34.86).
Spectra	Honeywell trade name for HMPE fiber.
Spun	Yarns which are formed by twisting short fibers together in the same manner as was done for natural fibers.
Staple	Short fibers, resembling the form of natural fibers, which are spun (twisted) together to form a yarn.
Twaron	Teijin Aramid trade name for aramid.
Working Load Limit	Minimum breaking strength divided by the factor of safety (SAE J2512).
Wrap	A single coil of wire rope wound on a drum (SAE J706).

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APPENDIX D. APPROVAL AUTHORITY.

CSTE-TM 9 October 2018

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure (TOP) 02-2-618 Towing and Recovery, Approved for Publication

1. TOP 02-2-618 Towing and Recovery, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

This TOP describes accepted methods used to measure, analyze, and report the towing and recovery capabilities of self-recovery, like-vehicle recovery, and dedicated recovery vehicles. Test procedures include safety, performance, and durability.

2. This document is approved for publication and will be posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Chief, Policy and Standardization Division

FOR

MICHAEL J. ZWIEBEL
Director, Test Management Directorate (G9)

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Policy and Standardization Division (CSTE-TM), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: Automotive Instrumentation Division (TEDT-AT-AD-I), U.S. Army Aberdeen Test Center. Additional copies can be requested through the following website: https://www.atec.army.mil/publications/documents.html, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.