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Aircraft ground equipment — Nose gear towbarless towing vehicle (TLTV) — Design, testing and maintenance requirements —

Part 1: Main line aircraft

Matériels au sol pour aéronefs — Tracteur sans barre (TLTV) de train avant — Exigences de conception, essais et entretien —

Partie 1: Aéronefs de ligne

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 9, *Air cargo and ground equipment*.

This second edition cancels and replaces the first edition (ISO 20683-1:2005), which has been technically revised.

A list of all parts in the ISO 20683 series can be found on the ISO website.

Introduction

This document specifies design, testing, maintenance and associated requirements to be applied on towbarless aircraft towing vehicles to be used on main line civil transport aircraft in order to ensure their operation cannot result in damage to aircraft nose landing gears, their steering systems, or associated aircraft structure.

Throughout this document, the minimum essential criteria are identified by the use of the key word “shall”. Other recommended criteria are identified by the use of the key word “should” and, while not mandatory, are considered to be of primary importance in providing safe and serviceable towbarless tractors. Alternative solutions may be adopted only after careful consideration, extensive testing and thorough service evaluation have shown them to be equivalent.

Aircraft ground equipment — Nose gear towbarless towing vehicle (TLTV) — Design, testing and maintenance requirements —

Part 1: Main line aircraft

1 Scope

This document is applicable to towbarless aircraft towing vehicles (TLTVs) interfacing with the nose landing gear of main line civil transport aircraft with a maximum ramp mass over 50 000 kg (110 000 lb). The requirements for regional transport aircraft with a lower maximum ramp mass are specified in ISO 20683-2. It is not applicable to TLTVs which were manufactured before its date of publication.

It specifies general design requirements, testing and evaluation requirements, maintenance, calibration, documentation, records, tracing and accountability requirements in order to ensure that the loads induced by the tow vehicle will not exceed the design loads of the nose gear or its steering system, or reduce the certified safe life limit of the nose gear, or induce a stability problem during aircraft pushback and/or gate relocation or maintenance towing operations.

This document specifies requirements and procedures for towbarless tow vehicles (TLTVs) intended for aircraft pushback and gate relocation or maintenance towing only. It is not intended to allow for dispatch (operational) towing (see Clause 3). Dispatch towing imposes greater loads on nose gears and aircraft structure due to the combination of speed and additional passenger, cargo, and fuel loads.

This document does not apply to towbarless towing vehicles interfacing with aircraft main landing gear.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Federal Aviation Regulations (FAR) 14 CFR Part 25, *Airworthiness Standards: Transport category airplanes,* paragraphs 25.301, *Loads*, and 25.509, *Towing loads*.[1)]

Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes CS-25, paragraphs 25.301, *Loads*, 25.509, *Towing loads,* 25.745(d*), Nose-wheel steering, and* AMC 25.745(d).[2)]

ISO 6966-1, *Aircraft ground equipment — Basic requirements — Part 1: General design requirements*

ISO 6966-2, *Aircraft ground equipment — Basic requirements — Part 2: Safety requirements*

1) FAR Part 25 constitute the U.S.A. Government transport aircraft airworthiness Regulations, and can be obtained from: US Government Printing Office, Mail Stop SSOP, Washington DC 20402-9328, U.S.A.

2) EASA CS25 constitute the European Governments transport aircraft airworthiness Regulations, and can be obtained from: European Aviation Safety Agency: Ottoplatz 1, D-50679 Cologne, Germany - http://easa.europa.eu/official-publication/.

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
main line aircraft
civil passenger and/or freight transport aircraft with a *maximum ramp mass* (3.3) over 50 000 kg (110 000 lb)

3.2
regional aircraft
civil passenger and/or freight transport aircraft with a *maximum ramp mass* (3.3) between 10 000 kg (22 000 lb) and 50 000 kg (110 000 lb)

3.3
maximum ramp mass
maximum ramp weight
MRW
maximum mass allowable for an aircraft type when leaving its parking position either under its own power or towed, comprising maximum structural take-off mass (MTOW) and taxiing fuel allowance

3.4
pushback
moving a fully loaded aircraft [up to *maximum ramp mass* (3.3) (MRW)] from the parking position to the taxiway. movement includes pick-up, push back with turn, a stop, a short push or tow to align aircraft and nose wheels, and release

Note 1 to entry: Engines may or may not be operating. Aircraft movement is similar to a conventional pushback operation with a tow bar. Typical speed does not exceed 10 km/h^{-1} (6 mph).

3.5
maintenance towing
movement of an aircraft for maintenance/remote parking purposes (e.g. from the parking position to a maintenance hangar

Note 1 to entry: The aircraft is typically unloaded with minimal fuel load (reference light gross weight, LGW), with speeds up to 32 km/h^{-1} (20 mph).

3.6
gate relocation towing
movement of an aircraft from one parking position to an adjacent one or one in the same general area

Note 1 to entry: The aircraft is typically unloaded with minimal fuel load (reference light gross weight, LGW), with speeds intermediate between pushback and maintenance towing.

3.7
dispatch towing
operational towing
towing a revenue aircraft [loaded with passengers, fuel, and cargo up to *maximum ramp mass* (3.3) (MRW)] from the terminal gate/remote parking area, to a location near the active runway, or conversely

Note 1 to entry: The movement may cover several kilometres with speeds up to or over 32 km/h^{-1} (20 mph), with several starts, stops and turns. Replaces typical taxiing operations prior to takeoff or after landing.

Note 2 to entry: In the definitions of the towing modes, the frequency of operation has not been included. This should not be interpreted to mean that no limitations are present. For limitations on the frequency of pushback and maintenance operations, refer to the appropriate airframe manufacturer's documentation or consult directly with the airframe manufacturer.

3.8
towbarless towing vehicle
TLTV
towing vehicle acting without tow bar on an aircraft's *nose landing gear* (3.9)

3.9
nose landing gear
NLG
aircraft nose landing gear in a tricycle landing gear layout

3.10
actual test gross weight
ATGW
reference aircraft mass for testing of the vehicle and aircraft, defined as the manufacturer's operating empty mass of the aircraft type concerned, plus fuel remaining in the tanks but lower than STGW

3.11
specified test gross weight
STGW
reference aircraft mass for testing of the vehicle and aircraft, defined as the manufacturer's operating empty mass of the aircraft concerned, plus at least 50 % of the maximum total fuel tanks capacity on the type, or its equivalent in mass (payload may be accounted if present, providing aircraft balance condition remains within limits)

3.12
maximum limits
limits (fore and aft tractive force, torsional or angular) established by the airframe manufacturer as not-to-exceed values intended to preclude possible damage to *nose landing gear* (3.9) or structure

Note 1 to entry: Maximum limits are established by airframe manufacturer's documentation and may be different for towbarless or tow bar towing operations. All aircraft load limits are limit loads as defined in FAR/EASA CS paragraph 25.301 (a).

3.13
operational limits
limits (fore and aft tractive force, torsional, or angular) which are set at a lesser value than the *maximum limits* (3.12) established by the airframe manufacturer

3.14
aircraft family
grouping of aircraft types or subtypes, defined by their manufacturer, for which the same *maximum limits* (3.12) may be applied

Note 1 to entry: A family usually encompasses all sub-types of a given type, but may also include other types. Testing for one (usually the lightest) model of the family results in towbarless towing approval for the whole family. See airframe manufacturer's towbarless towing evaluation documentation.

3.15
TLTV setting
grouping of aircraft types or sub-types, defined by the TLTV manufacturer, for which a single *operational limits* (3.13) setting is used

Note 1 to entry: A single TLTV setting usually encompasses aircraft types or sub-types, which may be produced by different airframe manufacturers, in a same defined MRW range.

3.16
drag load
tow force
total force from the tow vehicle on the nose gear tires in the *"X" axis* (3.17)

3.17
"X" axis
fore and aft axis of the tow vehicle, parallel to the ground

3.18
oversteer
exceedence of maximum torsional load or angular limits where potential damage to the *nose landing gear* (3.9) structure or steering system could take place

Note 1 to entry: These limits are defined in the appropriate airframe manufacturer's documentation. Torsional load limits typically occur after exceeding angular limits, but may occur before the angular limit is reached (e.g. nose gear hydraulic system bypass failure).

3.19
snubbing
sudden relief and reapplication of acceleration/deceleration loads while TLTV and aircraft are in motion

3.20
jerking
sudden application of push/pull forces from a complete stop

4 Design requirements

4.1 General

4.1.1 Towbarless tow vehicles (TLTVs) shall comply with the applicable general requirements of ISO 6966-1.

4.1.2 Airframe manufacturers should provide information for each aircraft type which allows TLTV manufacturers or airlines to self-test or evaluate the towbarless tow vehicles themselves.

Refer to the airframe manufacturer's documentation for evaluation requirements and detailed testing procedures that may be different from or additional to those contained in this document.

4.1.3 TLTV manufacturers should prepare and provide customers or regulatory agencies, as required, with a certificate of compliance or equivalent documentation, as evidence that successful testing and evaluation of a specific tow vehicle/aircraft type combination has been completed in accordance with this document and/or the applicable airframe manufacturer's documentation.

This certificate shall allow use of the vehicle on specifically designated aircraft models/types. The certificate should be established under an appropriate quality control program meeting the requirements of ISO 9001 or equivalent pertinent industry standard.

4.2 Towing loads

4.2.1 The push and pull towing forces induced by the TLTV onto the aircraft's nose landing gear as a result of either accelerating or braking shall be verified as per Clause 5 and/or Clause 6 hereafter, and shall not at any time exceed the maximum values specified by the aircraft manufacturer.

4.2.2 Depending on the range of aircraft types the TLTV is compatible with, preset towing load values may be used for a number of aircraft types or sub-types in a given MRW range.

In this case, each TLTV setting shall comply with the maximum limits specified by the manufacturer(s) of the designated aircraft types, sub-types, or family(s) thereof as defined by the aircraft manufacturers, and each TLTV setting shall be subjected to a separate verification.

4.3 Pick-up and holding system

4.3.1 The TLTV's nose landing gear pick-up/release device should operate in a smooth and continuous manner.

Abrupt or oscillating loads during the pick-up/release sequence should not occur. It should be designed to minimize the loads during the pick-up/release sequence. The drag loads induced during pick-up/release should fall well below the "peak" loads experienced during a typical operation.

4.3.2 The maximum loads induced by pick-up and release sequences shall be measured either on an aircraft or on a fixture representative of the nose gear geometry.

The vertical load on the nose gear or fixture shall be equal to the vertical load used for fatigue justification (refer to the appropriate airframe manufacturer's documentation). The maximum lift (height above the ground) of the nose gear shall not exceed the values given in the airframe manufacturer's documentation if such values are provided.

4.4 Oversteering protection

4.4.1 The maximum angular or torsional load limits stated by the aircraft's manufacturer in the event of oversteering shall not at any time be exceeded.

See aircraft manufacturer's TLTV assessment criteria document.

4.4.2 This may be achieved either by oversteer protection built into the TLTV, or by an oversteer alerting system being provided.

4.4.3 Oversteer protection may be achieved either by intrinsic design precluding the possibility of either limit being reached or exceeded or by a fail-safe oversteer protection system ensuring they shall not be exceeded.

Oversteer alerting shall consist in an appropriate fail-safe warning system installed on the TLTV, providing the driver with unmistakable indication that one of the maximum limits was reached.

4.4.4 No testing of the TLTV oversteer protection or alerting systems shall be performed on an in-service aircraft, in order to preclude any possible damage to the NLG structure or steering system.

Such testing should be accomplished with a suitable ground testing device representative of the specific aircraft model for which the TLTV is intended or through appropriate numeric simulation demonstration.

EASA CS requirements:

For aircraft registered or operated under EASA CS-25 *paragraph 25.745(d) and associated* AMC 25.745*(d)*, requires the TLTV manufacturers to provide a Declaration of Compliance (see 4.1.3) of their unit's oversteer protection or oversteer alerting system(s) with the present International Standard and the criteria published by the manufacturer of each aircraft type for which it is intended, and the aircraft manufacturers to list in their appropriate documentation the TLTV models that were specifically accepted for each aircraft type based on this Declaration of Compliance.

4.5 Nose wheels retention

4.5.1 The nose wheels shall be held by the vehicle in such a way that pitch-up of the aircraft shall not cause the wheel to disengage from the pick-up device at any nose gear steering angle.

A positive wheel retaining feature shall be provided. If the nose gear is "canted", a turning maneuver will cause uneven loading on the nose gear (i.e. for an aft canted gear, the vertical load on the inboard nose wheel will tend to increase and conversely, the vertical load on the outboard nose wheel will tend to decrease). The retention feature shall allow for uneven tire displacement without imposing additional loads on the nose gear.

4.5.2 The geometry of the holding device shall be such that no interference with aircraft structure may occur (e.g. torque links, weight and balance sensors, tires, water spray deflector, etc.) at all wheel steering angles up to the limits defined by the airframe manufacturer's documentation, and the full range of shock strut extensions and tire deflections.

Surface contact area between pick-up device and tire surface should be sufficient to preclude unacceptable tire loading (refer to tire manufacturer for bearing pressure specifications).

4.6 Safety

4.6.1 General

Towbarless tow vehicles (TLTVs) shall comply with the applicable safety requirements of ISO 6966-2.

4.6.2 Pick-up, release and associated loads

4.6.2.1 During the loading sequence, safety equipment shall inhibit any movement of the loading device if the nose wheel is not properly positioned.

Positive clamping and correct positioning of the nose wheel shall be ensured.

4.6.2.2 When the positioning pick-up/release sequence involves a relative motion between the vehicle and the aircraft, only the vehicle shall be allowed to move (see 4.2).

The aircraft parking brake should be applied or wheels properly chocked during this phase. TLTV design shall ensure that no loads higher than authorized are applied to the aircraft.

4.6.2.3 In order to avoid damage to the aircraft, the net load from all points of contact between the vehicle and nose gear tires shall be limited (on "X" axis) at a value lower than or equal to the operational limit.

Any single failure of the tow vehicle's load limiting system shall not cause loads which exceed the maximum limits.

4.6.2.4 If the pick-up/release sequences are fully automatic, an emergency stop or deadman switch shall allow the operator to freeze the sequence at any time.

An automatic or manual system shall allow reversal of the sequence and restore the starting position.

4.6.2.5 If aircraft type selection is necessary prior to the pick-up or towing/pushback sequence, a safety system in the vehicle shall inhibit further operation if the incorrect aircraft type is selected.

4.6.3 Acceleration, deceleration and associated loads

4.6.3.1 If towing is attempted while aircraft brakes are applied or wheel chocks are in place, a safety device on the TLTV shall limit the maximum static force to the safety limit as defined in 4.6.3.2 a).

4.6.3.2 The vehicle's maximum pulling and braking forces shall be limited to the maximum permissible nose landing gear loads of the aircraft (see airframe manufacturer's documentation and FAR/EASA CS paragraph 25.509).

One or two limiters shall be used.

a) A primary maximum load limiter, designed to the maximum load limits specified by the airframe manufacturer, shall be installed to limit the loads applied to the nose gear during all operations. It shall not be possible to override the limiter. Any activation of the maximum load limiter constitutes a recordable event.

b) A secondary operational load limiter, designed to lower operational loads, may be installed. If installed, whenever operational limits during acceleration or deceleration are exceeded, a safety system shall inhibit the further loading effort of the vehicle (engine back to idle or gear box to neutral without braking of the vehicle). The safety system shall allow resetting only when the vehicle is stopped. No record of the event is necessary.

4.6.3.3 Control of the loads may be based either on a limitation of the acceleration/ deceleration or on a limitation of the tow force/brake force. It may also be possible to control tow forces by controlling acceleration/deceleration.

4.6.4 Emergency braking

If an emergency braking system is incorporated or installed in the TLTV, the braking or decelerating load shall not exceed the maximum allowable nose landing gear limits, but it may exceed the operational limits. Emergency braking activation shall be well protected against inadvertent triggering.

4.6.5 Oversteer limits

4.6.5.1 Oversteer angular and torsional limits are not to be exceeded. Oversteer testing should not be performed on the aircraft.

4.6.5.2 For European registered or operated aircraft, the EASA CS-25 [CS 25.745(d)] require oversteer alert or protection systems on the aircraft or the TLTV (see 4.6.6). If a TLTV is designed to meet EASA CS-25 requirements, then testing to demonstrate vehicle oversteer limit alerting or protection functionality should be performed by the TLTV manufacturer in a suitable test facility or rig. TLTV manufacturers or airplane operators should consult with the airframe manufacturer or local aviation regulatory authorities, as appropriate, for current regulation status.

4.6.5.3 The maximum steering angle for conventional tow bar towing, as listed in the airframe manufacturer's documentation, is applicable for nose gear towbarless towing, unless otherwise noted.

Airframe manufacturers may establish different maximum steering limits between conventional tow bar and towbarless towing due to the absence of shear protection provided by traditional tow bar connections.

4.6.6 Oversteer alerting and/or protection

4.6.6.1 The tractor shall be equipped with a fail-safe oversteer alerting/indication or protection system that

a) activates an in-cab (red) warning light and audible alarm to indicate the maximum safety limit has been reached, and

b) requires a specific recordable action to complete the pushback/towing operation, in order to make it unmistakable to the tow vehicle driver that an inspection of the nose landing gear by an authorized engineer shall be initiated.

4.6.6.2 In addition, it is desirable that the device activates an in-cab (amber) warning light and audible signal to indicate an operational limit has been reached. The oversteer indication system shall allow sufficient time for the tow vehicle operator to take appropriate action to avoid reaching a safety limit.

4.6.6.3 The system shall be automatically activated when the airplane is coupled to the tow vehicle.

4.6.6.4 The oversteer indication and/or protection system shall be designed to protect the range of aircraft types that can be handled by the tow vehicle.

Oversteer is defined as exceeding maximum allowable steering angle or torsional load.

4.6.6.5 An optional system may provide a structural fuse (or other reliable load limiting system) on the tow vehicle which will prevent the application of torsional loads on the nose landing gear that exceeds the airframe manufacturer's specified maximum limit.

4.7 Testing operations

4.7.1 Snubbing and jerking

Snubbing and jerking effects or movements should be avoided during testing.

4.7.2 Vibrations

If severe or abnormal vibrations occur, testing should be discontinued and the cause determined.

4.7.3 Aircraft braking

The aircraft brakes should not be used while the aircraft is being towed by a TLTV, except in an emergency situation. Aircraft braking, while the aircraft is under tow, may result in loads exceeding the aircraft's design loads and may result in structural damage and/or nose gear collapse. For these reasons, it is recommended that airlines take appropriate steps to preclude aircraft braking during normal towbarless towing. The carrier's or airframe manufacturer's maintenance manual and operational procedures shall be complied with.

4.7.4 Stability

4.7.4.1 Attention shall be paid to aircraft stability. Stability may be affected by aircraft type, mass, centre of gravity location, weather condition, runway roughness, and slope. Stability shall be demonstrated by tests in accordance with the airframe manufacturer documentation.

4.7.4.2 The testing shall be conducted under maximum speed capability of the vehicle.

4.7.4.3 If a lateral instability is detected, a margin of 5 km/h (3 mph) shall be maintained between the speed at the beginning of instability and the maximum towing speed.

4.7.4.4 With minimal static load on the nose landing gear sufficient to move the airplane, no pitch oscillation of the aircraft shall occur, such that it would extend the shock absorber beyond the allowable strut extension in the ground mode.

4.7.4.5 Proper operational procedures shall be defined and followed to ensure vehicle and airplane stability.

4.8 Nose gear steering angle limit

The maximum steering angle for conventional tow bar towing, as specified in the airframe manufacturer's documentation, is applicable for nose gear towbarless towing, unless otherwise noted.

4.9 Vehicle classification

The TLTV model shall be classified according to its intended use, and tested accordingly, as either

a) category I: pushback only, or

b) category II: maintenance towing only, or

c) category III: both pushback and maintenance.

4.10 Placarding

Limitations and warnings imposed by all conditions shall be placarded in a location readily visible to the tow vehicle driver, including but not necessarily limited to the following:

a) classification category defined in 4.9;

b) types of aircraft the TLTV is qualified for (by TLTV setting if applicable);

c) maximum allowable speed;

d) maximum allowable towing angle, etc.

5 Testing requirements

5.1 General

5.1.1 No testing with an aircraft shall be performed if any requirement in Clause 4 is not met.

5.1.2 In case of a vehicle for which only partial qualification is required (e.g. pushback only), the tests performed shall be appropriate to its category classification per 4.7.

5.1.3 Dynamic numeric simulation may be used instead of the specified tests, unless prohibited by airframe manufacturer's documentation, and providing it guarantees at least equivalent results reliability.

5.2 Testing objectives

a) To measure the maximum values of the loads introduced into the airframe during extreme conditions, such as maximum acceleration and braking.

b) To verify that potential oversteer does not exceed the airframe manufacturer's specified limits. Also, to verify/demonstrate the capability of the TLTV to recognize steering angle or torsional load limits and to alert the vehicle operator accordingly. However, because of the potential for damage, no actual testing with an aircraft shall be performed for oversteer indication or protection calibration.

c) To verify the stability of the tow vehicle/aircraft combination throughout the total range of operational speeds.

d) To evaluate the fatigue loads introduced into the airframe by normal utilization of the vehicle during the specific category of operations for which qualification is intended.

5.3 Aircraft configuration

5.3.1 Before any calibration or testing is accomplished, all landing gear shall be properly serviced as defined by the airframe manufacturer's instructions.

5.3.2 Aircraft weights, light and heavy gross weight and C.G. position for testing shall be in accordance with the requirements in the calibration and test requirements (see 5.4 and 5.5) and the airframe manufacturer's documentation.

The airframe manufacturer (see Bibliography) should be consulted for any deviation from documented weights.

5.3.3 The aircraft shall be in the correct towing configuration as defined by the airframe manufacturer's maintenance and operational documentation.

5.4 Calibration

5.4.1 General

5.4.1.1 Tests may be performed with an instrumented aircraft or an instrumented towing vehicle. Calibration of both are discussed in this clause (see 5.5.1 for restrictions in the use of instrumented vehicles).

5.4.1.2 To measure fore and aft tow loads on the nose landing gear, strain gauges shall be installed at the nose gear locations (drag brace, torque arm, or other components) specified by the airframe manufacturer.

Calibration of the strain gauges is accomplished by pushing and pulling the nose gear with known tow loads.

5.4.1.3 To measure fore/aft and torsional tow loads on the TLTV, strain gauges shall be installed at vehicle locations specified by the vehicle manufacturer and shall be calibrated to a known tow load input.

5.4.1.4 Once the strain gauges have been calibrated, the aircraft can be towed with the TLTV and the tow loads can be determined directly from the strain measurements.

The following procedure outlines how to calibrate the strain gauges.

5.4.2 Aircraft calibration

5.4.2.1 The calibration test shall be performed with known tow/torsional loads. Using an X-Y plotter, the microstrain (X-axis) is plotted against the known tow load input (Y-axis) (see examples in Figure 1 and Figure 2). The slope of the line is the calibration factor.

5.4.2.2 Instrumentation requirements for calibration are as follows:

a) nose gear measured output in microstrain;

b) calibrated input tow load (kN);

c) both the strain gauges and strain gauge circuits shall be temperature compensating. Other compensating requirements such as bending of the drag brace/torque link may be specified by the aircraft manufacturer. Selection of strain gauges, bonding material, gauge protection, etc., should take into account the type of material being gauged and any possible adverse conditions that could occur during testing.

5.4.2.3 Calibration

a) Calibration tests may be accomplished at the "light" and "heavy" reference test weights for the particular aircraft model being tested, to be specified by the airframe manufacturer. However, if calibration is to be done at only one weight, the "heavy" test weight (HGW) shall be used in order to be conservative.

b) Calibration shall be performed with the aircraft and wheels placed on a level and smooth surface.

c) Immediately prior to calibration testing, the nose gear strut extension shall be recorded.

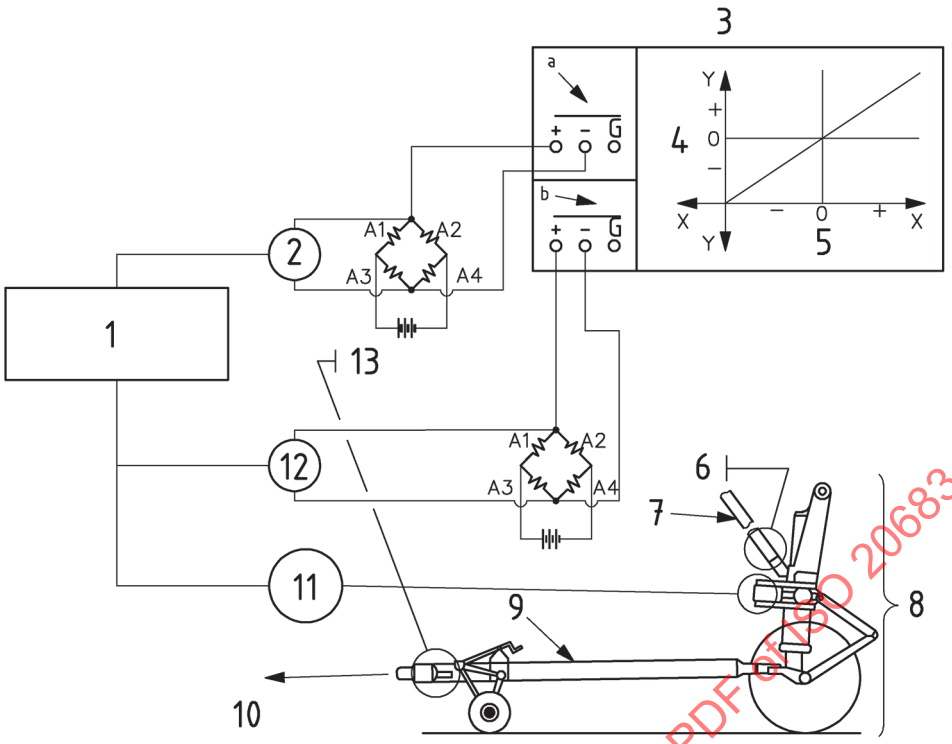
d) All calibration tests shall be performed with all main gear tires chocked and aircraft parking brake set.

e) Using the known tow load input, the aircraft shall be pushed and pulled while plotting microstrain versus tow load. Two push/pull tests shall be performed at 0° nose gear steering angle.

f) For 0° nose gear steering angle, the calibration load shall be from 10 % to approximately 50 % but not to exceed 75 % of the aircraft limit tow load as specified by the airframe manufacturer. If main gear tire slipping or skidding occurs, the calibration is not valid and shall be repeated.

g) The calibration plots shall be linear. If the two calibration plots at 0° steering angle differ by more than 5 %, appropriate action should be taken to improve measurement repeatability. If any nonlinearities exist in the calibration plots, appropriate adjustments to the test instruments should be made.

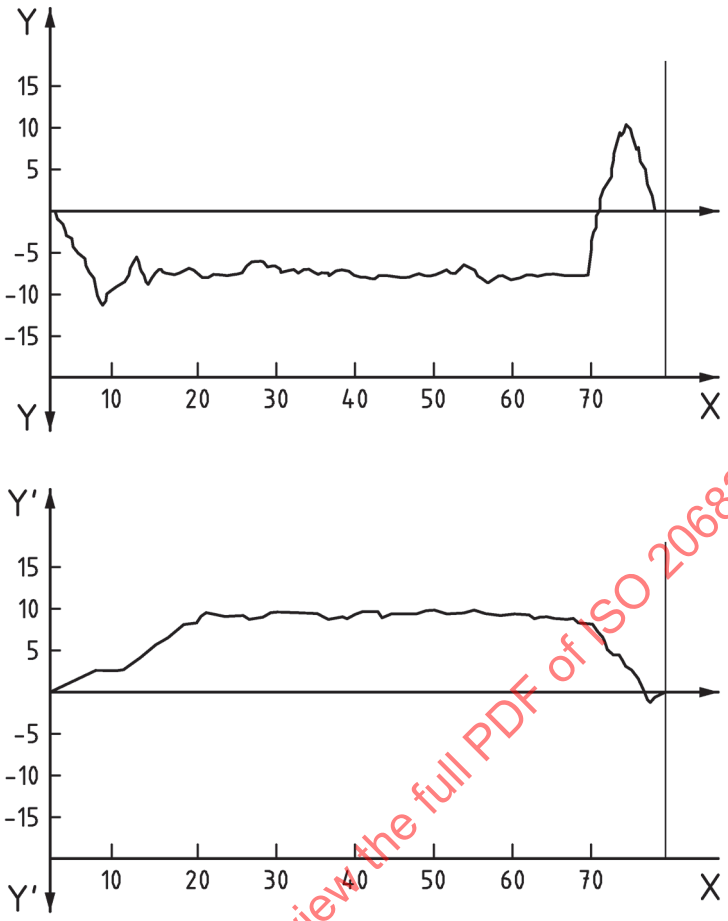
h) If the criteria through 5.4.2.3 g) above are satisfied, the relevant calibration factor may be used to convert strain gauge measurements directly to tow load during towbarless vehicle testing.



Key

1 digital recording instrument
2 force input
3 X-Y recorder
4 tow force
5 drag brace strain
6 drag brace bridge circuit
7 drag brace
8 nose gear structure
9 conventional towbar
10 forward
11 steering angle input
12 strain input
13 calibrated test towbar transducer
a Y input.
b X input.

Figure 1 — Tow load calibration



Key

Y load

Y′ velocity

X time (seconds)

Figure 2 — Example of calibration test results (load history example and velocity history example)

5.4.3 TLTV calibration

5.4.3.1 The calibration test shall be performed with a known tow/torsional load.

Using an X-Y plotter, the microstrain (X-axis) is plotted against the known tow load input (Y-axis) (see Figure 2). The slope of this line is the calibration factor.

5.4.3.2 Instrumentation requirements for calibration: the instrumentation requirements are to be specified by the vehicle manufacturer and shall be in accordance with current state of the art techniques.

5.4.3.3 Calibration

a) The calibration procedure shall be specified in writing by the tow vehicle manufacturer.

b) The calibration loads shall include loads from 10 % to 50 % of the aircraft limit load for which the aircraft qualification is requested, as specified by the airframe manufacturer.

c) Influence of vertical and side loads, as defined by the airframe manufacturer's documentation, shall be considered during calibration.

d) The calibration plots shall be linear. If the two calibration plots differ by more than 5 %, appropriate action should be taken to improve measurements repeatability. If any nonlinearities exist in the calibration plots, appropriate adjustments to the test instruments should be made.

e) If the criteria through 5.4.3.3 d) are satisfied, the relevant calibration factor may be used to convert strain gauge measurements directly to tow load during towbarless vehicle testing.

5.4.4 Oversteering calibration

Calibration of TLTV oversteer detection systems, either angular or torsional load, shall be accomplished in a suitable test facility by the vehicle manufacturer. Calibration shall not be performed on in-service aircraft because of potential risk of damage to nose landing gears or aircraft structure. Maximum allowable limits are determined by the airframe manufacturer's documentation.

5.5 Testing procedures

5.5.1 General

5.5.1.1 Prior to the tests

a) A check shall be performed on the clearances between any part of the aircraft and tow vehicle structural parts as described in 4.5.2 and provided in the test report.

b) Instrumentation should be in a serviceable condition and all items should have a valid calibration certificate.

5.5.1.2 Tests may be performed with an instrumented aircraft and/or an instrumented towing vehicle.

Towing load measurements on the vehicle are restricted to cases where accurate tow load measurements are possible (example: where pick-up device geometry allows accurate measurements).

5.5.1.3 Once calibration of the nose gear or tow vehicle strain gauges is accomplished, towbarless towing tests can be performed and tow loads can be measured directly.

For any change in weight or C.G. of the aircraft, the instrumentation should be "zeroed" just prior to testing.

5.5.1.4 During testing, the steering angle should not exceed steering angle limits specified by the airframe manufacturer.

5.5.1.5 All tests shall be performed on typical airport taxiways.

5.5.2 Data recording

5.5.2.1 During testing, the following data shall be recorded on a time-history chart (see example Figure 2):

a) calibrated nose gear drag loads in units of force (kN) (Y-axis of chart);

b) towing speed (km/h) (Y-axis of chart);

c) time (seconds) (X-axis of chart).

5.5.2.2 Data should be recorded analogically or at a minimum sampling rate of 30 samples/second (30 Hz).

5.5.2.3 The following data should be recorded prior to commencement of the tests:

a) aircraft gross weight;

b) aircraft Center of Gravity location;

c) strut extension for all landing gear, for each gross weight tested (not applicable to in-service fatigue evaluation trials);

d) runway surface conditions during testing [e.g. dry runway, 24 °C (75 °F), etc.] (not applicable to in-service fatigue evaluation trials);

e) aircraft model and registration or serial number.

6 Evaluation

6.1 Evaluation criteria

6.1.1 Tests shall be performed in order to evaluate the following conditions:

a) normal condition testing;

b) stability testing;

c) extreme condition testing.

6.1.2 In order to minimize testing cost, complexity and duration while gathering all of the required data:

a) the defined testing program shall be appropriate to the intended vehicle classification (see 4.9);

b) testing should preferably use test rigs simulating the aircraft interface whenever possible (e.g. static testing), and shall use such devices whenever necessary to avoid a risk of damaging the aircraft (e.g. oversteering testing);

c) trials should preferably be performed during in-service aircraft handling operations.

6.2 Normal condition testing

6.2.1 Testing methods

Normal condition tests shall be performed according to the intended use and classification of the tow vehicle (maintenance towing and / or only pushback), and may be performed in either of two ways:

a) by means of in-service trials, or

b) by means of dedicated trials specifically meant for the evaluation.

6.2.2 Tests number

The number of tests should be specified by the airframe manufacturer. If no specific number of tests is required, the numbers specified in 6.2.3, 6.2.4 and 6.2.5 shall apply.

6.2.3 Pushback

A total of 45 pushbacks shall be performed with three different tow vehicle drivers (15 trials each), as follows.

a) The pushback manoeuvres shall consist of an aft tow, with turn, and a short push or tow to align the nose gear parallel to the taxiway.

b) Each pushback should be performed either under operational flight departure conditions or in a manner that simulates typical in-service pushback conditions (i.e. typical speed, starts, stops, turns, distance, etc.) as judged by each driver.

c) The pushback tests shall be performed either under operational flight departure conditions or at the reference test weight defined with the manufacturer.

d) The pushback tests shall be performed with aircraft engines off.

e) Aircraft gross weights, the number of drivers and engines off and on status shall be recorded.

6.2.4 Maintenance towing

A total of 45 maintenance towings shall be performed with three different tow vehicle drivers, each driver performing 15 trials, as follows:

a) each maintenance towing is an individual start-stop cycle;

b) it shall either be conducted under operational maintenance towing conditions or simulate typical maintenance conditions (typical speed, turns and distance);

c) approximately 80 % of the loaded towing vehicle maximum speed shall be reached and stabilized between each stop;

d) the trials shall be performed either under the operational maintenance towing weights encountered or under the reference weights defined with the airframe manufacturer. In either case, qualification of the tractor shall be limited to the highest weight effectively tested.

6.2.5 Pick-up and release

A total of 15 pick-up and releases shall be performed at the same weights used for either pushback or maintenance towing according to intended use and classification (see 4.7) of the tow vehicle. Should the operation not be fully automatic, 3 different drivers shall perform the test. In case of in-service trial, this phase may be included as part of the pushback and/or maintenance towing tests.

6.2.6 Test evaluation

The number of tests shall be specified by the airframe manufacturer. If no specific of tests are required, the numbers as specified in 6.2.3, 6.2.4 and 6.2.5 shall apply.

The test weight shall be defined by the airframe manufacturer. If the requested test weight cannot be achieved, tests at a lower weight can be performed. The tow forces for evaluation hereafter shall be calculated in the following manner:

$$F_{\text{final}} = F_{\text{test}} * \frac{\text{STGW}}{\text{ATGW}} * \left[1,2 - 0,2 \frac{\text{OWE-ATGW}}{\text{OWE-STGW}} \right] \quad (1)$$

where

F_{final} is the force value for test evaluation;

F_{test} is the actual measured force value;

STGW is the specified test gross weight;

ATGW is the actual test gross weight;

OWE is the operating weight empty.

Formula (1) results in a penalty factor of 1,2 when tests are made at OWE and a factor of 1,0 when tests are made at STGW. For testing performed at weight greater than STGW, a factor of 1,0 shall be applied.

6.3 Stability testing

6.3.1 These tests are to ensure TLTV-aircraft stability over the velocity range capability of the vehicle during typical runway conditions and towing operations.

6.3.2 The tests shall be performed under aircraft reference test weight and the maximum speed attainable by the aircraft and tow vehicle assembly.

6.3.3 Two trials under these conditions shall be performed, and their results recorded. For each test, the required speed shall be attained and maintained for a minimum of 20 s.

6.3.4 For the range of speeds thus tested, the TLTV should not induce oscillation or vibration loads on the nose gear.

The tow vehicle shall also demonstrate stability over the vehicle's full operational range including starts, stops and turns. For safety purposes, turns may be at less than the defined test speed. If either the data or the vehicle driver indicate instabilities or oscillatory loads, the tow vehicle's maximum speed should be limited to a speed that is at least 5 km/h (3 mph) below the speed at which the instability was detected.

6.4 Extreme condition testing

6.4.1 Testing methods

Extreme condition tests shall be performed according to the intended use and classification of the tow vehicle (maintenance and / or only pushback), and include

a) static testing, and

b) loads measurement and assessment during maximum towbarless tow vehicle acceleration and braking.

6.4.2 Static load tests

Four static load tests shall be performed as follows:

a) with the aircraft/tow vehicle stopped on the taxiway, apply full aircraft brakes;

b) keeping the aircraft brakes on, progressively and quickly apply full vehicle power. Maintain maximum vehicle power for 5 s. Repeat two push and two pull tests for a total of four trials;

c) the trials can be conducted at any aircraft weight. The test should be conducted with dry conditions to prevent abnormal sliding of the aircraft or spinning of the vehicle wheels.

If the subject TLTV and overload limiter devices have never been tested before, it is highly recommended to perform these tests with a simulated aircraft interface test rig.

6.4.3 Maximum acceleration and braking

Maximum accelerations and braking tests shall be accomplished as follows:

a) from a dead stop, use maximum power of the tow vehicle to accelerate until the desired velocity is reached;

b) once the target velocity is reached, maintain that velocity until the tow vehicle and aircraft stabilize. Once stabilized, apply tow vehicle maximum braking until the aircraft comes to a complete stop;

c) perform the push tests similar to the pull tests, except push the aircraft aft instead of pulling the aircraft forward. The braking and acceleration procedures are the same for the push tests;

d) acceleration and braking tests are designed to check the vehicle's full capability. Therefore, drivers should apply the brakes as hard as possible and accelerate as quickly as possible;

e) Table 1 hereafter outlines the acceleration/braking trials and sequence:

Table 1 — Acceleration/braking trials and sequence

Direction	Pull tests				Push tests	
Velocity	5	10	20	max	5	10
Km/h (mph)	(3)	(6)	(12)		(3)	(6)
Number of trials	2	2	2	2	2	2
Test sequence	1	2	3	4	1	2

6.5 Oversteer testing

No testing of the TLTV oversteer indication and protection system shall be performed on an in-service aircraft. This precaution is to preclude any possible damage to the nose landing structure or steering system. Such testing should be accomplished with a suitable ground testing device representative of the specific aircraft model for which the TLTV is intended to be used. However, if the TLTV oversteer limits are appreciably lower than the maximum limits specified by the airframe manufacturer, then confirmation or confidence checks of these lower limits may be performed with an in-service aircraft.

7 Maintenance

7.1 General

7.1.1 The present Clause covers the special requirements and procedures for inspection, maintenance and calibration of towbarless tow vehicles (TLTV) tractive force and steering protection systems or alerting devices, where necessary to ensure protection of the aircraft.

7.1.2 The TLTV aircraft NLG tractive force and steering protection systems or alerting devices which, in the event of failure or malfunction, would as a consequence of failure not preclude potential damage to the aircraft's nose landing gear and its steering system shall be inspected, maintained, tested and calibrated to the TLTV manufacturer's requirements for its classification on all the designated aircraft types which the TLTV is designed to handle.

7.1.3 Inspection, maintenance and calibration schedules, any special tools and training requirements for the TLTV's protection systems or alerting devices shall be available.

7.1.4 The TLTV's aircraft NLG protection systems or alerting devices shall be inspected, maintained and calibrated in accordance with the requirements of this document and the TLTV manufacturer's maintenance manuals and schedules.

7.1.5 The organization responsible for the maintenance of the TLTV shall keep documented records of each TLTV's aircraft NLG protection systems or alerting devices inspection, maintenance and calibration

in maintained files to be made available for review and audit by the aircraft airworthiness regulatory authorities when requested.

7.1.6 Records should be kept for a minimum period of two years or in accordance with the requirements of the controlling aircraft airworthiness regulatory authority.

7.2 Maintenance manual

The TLTV manufacturer's maintenance manual shall incorporate a separate section covering the inspection, maintenance and calibration of the TLTV aircraft NLG steering and tractive force protection systems or alerting devices. The maintenance manual shall

— detail the scope of the aircraft NLG steering and tractive force protection systems or alerting devices,

— list applicable reference documents,

— list applicable equipment required to perform the inspection, calibration and maintenance tasks,

— include trouble shooting sections,

— list inspection, maintenance and calibration intervals,

— list all items to be checked/calibrated, and

— detail against each task full instructions on how the task/calibration should be carried out.

7.3 Requirements

7.3.1 The TLTV manufacturer shall publish inspection, calibration and maintenance checklists for each model of TLTV.

7.3.2 Each check list shall

a) detail the scope of the checklist,

b) list applicable reference documents,

c) list applicable equipment required to perform the inspection, calibration and maintenance tasks,

d) list inspection, maintenance and calibration intervals in hours run and/or calendar interval,

e) list all items to be checked/calibrated on the TLTV aircraft NLG steering and tractive force protection systems or alerting devices,

f) provide for the TLTV serial/chassis/fleet number to be recorded,

g) provide for a task reference number to be recorded,

h) provide for details of defects and actions required to be recorded,

i) provide for each checkable item/task to be signed off and dated when complete by the qualified and authorized person completing the task,

j) provide for the completed checklist to be signed off by the qualified and authorized person completing the tasks and counter signed and dated by an authorized person when all tasks and actions have been completed.