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International Standard ISO 4138

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Road vehicles — Steady state circular test procedure

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 4138 was developed by Technical Committee ISO/TC 22, *Road vehicles*, and was circulated to the member bodies in July 1980.

It has been approved by the member bodies of the following countries :

Austria	Egypt, Arab Rep. of	Poland
Belgium	France	Romania
Brazil	Germany, F. R.	South Africa, Rep. of
Canada	Italy	Spain
Chile	Japan	Sweden
China	Korea, Dem. P. Rep. of	Switzerland
Czechoslovakia	Netherlands	United Kingdom

The member bodies of the following countries expressed disapproval of the document on technical grounds :

USA
USSR

Road vehicles — Steady state circular test procedure

0 Introduction

0.1 General remarks

The road holding ability of a road vehicle is a most important part of active vehicle safety. Any given vehicle, together with its driver and the prevailing environment, makes a closed-loop system that is unique. The task of evaluating road holding ability is therefore very difficult because of the significant interaction of these driver-vehicle-road elements, each of which is in itself complex. A complete and accurate description of the behaviour of the road vehicle must necessarily involve information obtained from a number of tests of different types.

Because they quantify only one small part of the whole handling field, the results of this test can only be considered significant for a correspondingly small part of the overall vehicle handling behaviour.

Moreover, nothing is known about the relationship between the results of this test and accident avoidance. A very large amount of work is necessary to acquire sufficient and reliable data on the correlation between handling properties in general and accident avoidance.

In addition, up to now, no significant correlation has been found between the vehicle behaviour and the driver's subjective evaluation during the test. However, some correlation has been found to exist between certain aspects of a skilled driver's subjective evaluation during road driving and the results of the steady state circular test.

Therefore it is not possible to use this procedure and the test results for regulation purposes at the moment. The best that can be expected is that the steady state circular test can be used as one among many other, mostly transient, tests which together can cover the field of vehicle dynamic behaviour.

0.2 Object of the test

This procedure requires the test vehicle to be driven at several constant[1] speeds on a path of known radius. The directional control response characteristics are determined from data obtained while driving the vehicle at successively higher speeds on the constant radius path (or path of sufficient length to attain steady state). This procedure can be conducted in a relatively small area. The procedure can be tailored to existing test track facilities by selecting a circle or path of appropriate radius. Often a constant radius (in plane) road will suffice for a test facility.

The primary object of this test is to measure the steering wheel angle as a function of lateral acceleration and to describe vehicle steering (for example, understeer/oversteer) behaviour for left hand and right hand turns.

Thus it is necessary to measure :

— steering wheel angle;

— lateral acceleration (alternatively, this may be determined from other variables).

NOTE — Strictly speaking, test results based on lateral acceleration should not be used for comparison of the performance of different vehicles. This is because lateral acceleration, as precisely defined, is measured at right angles to the vehicle x-axis* and not at right angles to the tangent of the vehicle path.

To overcome this difficulty, lateral acceleration may be corrected for vehicle sideslip angle, which gives the quantity "centripetal acceleration".

However, the extent of this correction is not likely to exceed a few percent and can generally be neglected.

* As referred to an axis system defined as follows :

A right-hand orthogonal axis system fixed in the vehicle such that its origin is at the centre of gravity of the vehicle. The x-axis is in the longitudinal direction, the y-axis is in the lateral direction and the z-axis is vertical.

It is desirable to measure :

— sideslip angle. If the whole of the procedure described in annex C is to be followed, the sideslip angle must be measured directly or calculated from other measured variables (see 3.2.5).

The following variables can also be measured :

— yaw velocity;

— forward velocity;

— steering wheel torque;

— vehicle roll angle.

1) This may depend on the test procedure to be used (see note in clause 5).

1 Scope and field of application

This International Standard specifies a procedure for determining the steady state directional control response of passenger cars, as defined in ISO 3833, by measuring the steady state cornering behaviour which is one of the factors composing vehicle dynamics and road holding properties.

The definitions of the technical terms used in this document are given in annex E.

2 References

ISO 1176, *Road vehicles — Masses — Vocabulary.*[1)]

ISO 2416, *Passenger cars — Load distribution.*

ISO 3833, *Road vehicles — Types — Terms and definitions.*

3 Instrumentation

3.1 Description

Those of the variables listed in 0.2 which are selected for test purposes shall be monitored, using appropriate transducers, and the data shall be recorded on a multi-channel recorder having a time base. The normal operating ranges and recommended maximum errors of the transducer/recording system are as shown in table 1.

Table 1

Variable	Range	Recommended maximum error of the combined transducer/recorder system
Steering wheel angle	± 360°[2)]	± 2° for angles < 180° ± 4° for angles > 180°
Lateral acceleration	± 15 m/s²	± 0,15 m/s²
Yaw velocity	± 50°/s	± 0,5°/s
Forward velocity	0 to 50 m/s	± 0,5 m/s
Sideslip angle	± 15°	± 0,5°
Steering wheel torque	± 30 Nm	± 0,3 Nm
Roll angle	± 15°	± 0,15°

NOTE — These values are tentative and provisional until more experience is available. The minimum overall bandwidth of the entire measurement system including transducers and recorder shall be 3 Hz.

3.2 Installation

Transducer installation and orientation will vary according to the type of instrumentation used. However, if a transducer does not measure directly the required variable, appropriate corrections for linear and angular displacement shall be made to its signals so as to obtain the required level of accuracy.

3.2.1 Steering wheel angle

A transducer shall be installed, as specified by the manufacturer, to obtain steering wheel angle relative to the sprung mass.

3.2.2 Lateral acceleration

An accelerometer shall be installed as specified by the manufacturer and mounted either :

a) on the sprung mass at the whole vehicle centre of gravity and aligned with the vehicle y-axis. In this case it will measure "side acceleration" and its output shall be corrected for the component of gravity on the accelerometer axis due both to the vehicle roll angle and any track surface inclination.

b) on the sprung mass at any position and aligned parallel to the vehicle y-axis. In this case, its output shall be corrected for its position relative to the centre of gravity, which will give "side acceleration"; which in turn shall be corrected for the component of gravity on the accelerometer axis due both to vehicle roll angle and any track surface inclination.

c) on a reference trolley such as may be used to measure vehicle roll angle and sideslip angle. In this case corrections shall be made both for its position relative to the vehicle centre of gravity and for any track surface inclination.

3.2.3 Yaw velocity

A transducer shall be installed, as specified by the manufacturer, with its axis aligned with or parallel to the vehicle z-axis.

3.2.4 Forward velocity

A velocity transducer shall be installed as specified by the manufacturer. If it is not aligned so as to operate in the x-z plane and parallel to the test track surface, its output shall be corrected for any linear or angular displacement therefrom.

1) At present at the stage of draft. (Revision of ISO 1176-1974.)

2) Assuming conventional steering system.

3.2.5 Sideslip angle

A transducer shall be installed, as specified by the manufacturer, so as to measure sideslip angle. If it does not measure the angle in the plane of the track surface, an appropriate correction shall be made.

Sideslip angle can be calculated from coincident measurements of other variables, for example, lateral and forward velocity at any point on the vehicle.

The point of the vehicle to which the output of the transducer is referred shall be indicated in Annex A.[1]

3.2.6 Steering wheel torque

A transducer shall be installed, as specified by the manufacturer, so as to measure the torque applied to the steering wheel about its axis of rotation.

3.2.7 Roll angle

A transducer shall be installed, as specified by the manufacturer, so as to measure the angle between the vehicle y-axis and the track surface.

4 Test conditions

4.1 Test track

All tests shall be carried out on a uniform hard surface which is free of contaminants and which has a gradient, as measured over a distance of 5 m up to 25 m in any direction, of not more than 2 %. For a standard test condition, a smooth, dry pavement of asphalt or cement concrete or a high-friction test surface is recommended. A minimum radius of 30 m is recommended and the ambient wind speed shall not exceed 7 m/s. For larger radii where vehicle speeds are higher, a lower maximum wind speed is desirable.

4.2 Tyres

The test may be performed with tyres in any state of wear so long as, at the end of the test, a minimum of 1,5 mm of tread depth remains over the whole circumference of the tyre (see note).

However, for a standard tyre condition, new tyres shall be used after being run-in for 150 to 200 km in the appropriate position on the test car without excessive harsh use, for example braking, accelerating, cornering, kerbing etc.

Tyres shall be inflated to the pressure specified by the vehicle manufacturer for the test vehicle configuration. The tolerance for setting the cold pressure is ± 0,05 bar for pressures up to 2,5 bar and ± 2 % for pressures above 2,5 bar.

NOTE — As in certain cases, the tread depth has a significant influence on test results, it is recommended that it should be taken into account when making comparisons between vehicles or between tyres.

The circumference is that part of the tyre which contacts the road surface when the vehicle is stationary and the steered wheels are in the straight-ahead position.

4.3 Operating components

All operating components likely to influence the results of this test (for example, shock absorbers, springs and suspension parts) shall be inspected to ensure that they meet the manufacturer's specifications and are properly adjusted and secure.

4.4 Vehicle loading conditions

4.4.1 General conditions

In no case shall the maximum manufacturer's total mass and the maximum manufacturer's axle load, both as defined in ISO 1176, be exceeded. The complete vehicle kerb mass as defined in ISO 1176, shall be regarded as the minimum mass.

4.4.2 Minimum loading condition

The total vehicle mass for the minimum loading condition shall consist of the complete vehicle kerb mass (see 4.4.1), plus the masses of the driver and instrumentation.

4.4.3 Maximum loading condition

For the maximum loading condition, the total mass of a fully laden vehicle shall consist of the complete vehicle kerb mass, (see 4.4.1) plus 68 kg for each seat in the passenger compartment, and the maximum luggage mass equally distributed over the luggage compartment according to ISO 2416. Loading of the passenger compartment shall be such that the actual wheel loads are equal to those obtained by loading each seat with 68 kg according to ISO 2416. The mass of instrumentation shall be included in the vehicle mass. Care shall be taken to give minimum error in the location of the centre of gravity and in the values of the moments of inertia as compared to the loading conditions of the vehicle in normal use.

5 Test procedure

The tyres shall be warmed up by a procedure equivalent to driving 500 m at a lateral acceleration of 3 m/s^2 on the radius to be used for the tests and the pressures may be recorded.

The vehicle shall be driven on the desired circle at the lowest possible speed. Data shall be recorded with the steering wheel position and throttle position fixed.

1) It is recommended that the centre of gravity or the point of intersection between a line connecting the rear wheel centres and the vehicle's longitudinal median plane are used as reference points.

The vehicle shall then be driven at the next speed at which data are to be taken. However, if the instrumentation requires to be reset between the tests, the vehicle may be stopped for this purpose. Data shall be taken in increments on not more than 0,5 m/s^2. Where the data vary rapidly with lateral acceleration, it may be useful to take data in smaller increments.

At each lateral acceleration level, the steering wheel position and throttle position shall be maintained as constant as possible while data are taken. Whatever radius is chosen, the path shall be followed to within 0,3 m of either side. Data shall be taken for at least 3 s at each steady state lateral acceleration level. It is recommended that the highest gear compatible with the conditions of the test should be used.

NOTE — It may be possible to carry out the test by accelerating very slowly through the speed range and recording the variables continuously. Further work is required before this can be specified as an alternative procedure.

The value of the lateral acceleration shall be increased and data shall be taken until it is no longer possible to maintain steady state conditions.

Data shall be taken for both left and right turns. All the data may be taken in one direction followed by all the data in the other direction. Alternatively, data may be taken successively in one direction and in the other for each acceleration level, going from the lowest to the highest. The method chosen shall be noted in the general data.

6 Data analysis

6.1 General

When analysing the data, the steady state values[1] for all the measured variables shall be established as the average values of these variables in the elapsed time during which the steady state was maintained.

If vehicle speed is used to compute lateral acceleration and it is measured by timing the vehicle over a known distance, the time interval used for estimating speed shall be sufficiently long to measure speed to ± 2 % (i.e. lateral acceleration ± 4 %). For example, if a 45 m radius circle is tracked at 13 m/s and the strip chart is considered to read time to 0,1 s accuracy, the timing length shall be not less than 65 m, i.e.

$$13 \text{ m/s} \times 0{,}1 \text{ s} = 1{,}3 \text{ m}$$

$$1{,}3 \text{ m} = 0{,}02 \times x$$

$$x = \frac{1{,}3}{0{,}02} = 65 \text{ m}$$

and 65 m represents about one quarter revolution on a 45 m radius circle.

6.2 Steering wheel angle

If the steering wheel angle varies by more than 10° from the average value, the data, if used, shall be so labelled.

6.3 Lateral acceleration

Steady state levels of lateral acceleration may be obtained by any one of the following four methods :

a) The corrected output of an accelerometer (see 3.2.2).

b) The product of the yaw velocity, corrected for vehicle roll angle, and the forward velocity corrected for sideslip angle.

c) The square of the forward velocity, corrected for sideslip angle, divided by the path radius.

d) The product of the square of the yaw velocity, corrected for vehicle roll angle, and the path radius.

7 Data presentation

General data shall be presented on a summary form as shown in annex A.

Measured data shall be plotted on figures of annex B as follows :

— vehicle steering wheel angle data points on figure 1;

— vehicle sideslip angle data points if measured, on figure 2;

— vehicle roll angle data points if measured, on figure 3;

— steering wheel torque data points if measured, on figure 4.

NOTE — There are a number of ways of further processing the data presented in this clause. These ways have been developed as conventions over many years and each can be justified in its own way; for example the division of steering wheel angle data by a nominal overall steering ratio.

This is particularly true where the process involves fitting smooth curves to experimental data for the purpose of evaluating the gradients. The type of curve and the method of fitting will influence the results obtained and several different types of curves have been used.

Within the context of an International Standard it is not possible to recommend any one way as being better than any other.

Therefore, a number of ways of processing the test data, to produce new variables which describe vehicle steady state behaviour, are described in annex C. Any one of those ways may be used at the option of the user. If the processing described in annex C is carried out, it will be necessary to determine the overall steering ratio as described in annex D.

1) See note under clause 5.

Annex A

General data

Vehicle identification :

Make, year, model, type :	....
Vehicle number :	....
Steering type :	....
Suspension type — Front :	....
Rear :	....
Engine size, optional equipment :	....
Tyres and condition :	....

Tyre pressures

if measured	— Cold	Front....................	Rear....................	bar
	— Hot — after warm up	Front....................	Rear....................	bar
	— Hot — after test	Front....................	Rear....................	bar

Rims :	....
Wheelbase :	....m
Track Front :	....m
Rear :	....m
Other : (In particular, relevant suspension settings)	....m

Vehicle loading :

Loading condition and location : ....

Vehicle mass as tested :

LF....................	RF.................... kg
LR....................	RR.................... kg

TOTAL..kg

....

Test conditions

Test surface description	....
Weather conditions	....
Temperature	....°C
Wind speed	....m/s
Reference point for sideslip angle (see 3.2.5)	....
	....
Test path radius	....m
Sequence of test runs (see clause 5)	....

Annex A (continued)

General data

Test personnel :

Driver ....

Observer ....

Data analyst ....

General comments :

Annex B

Presentation of results

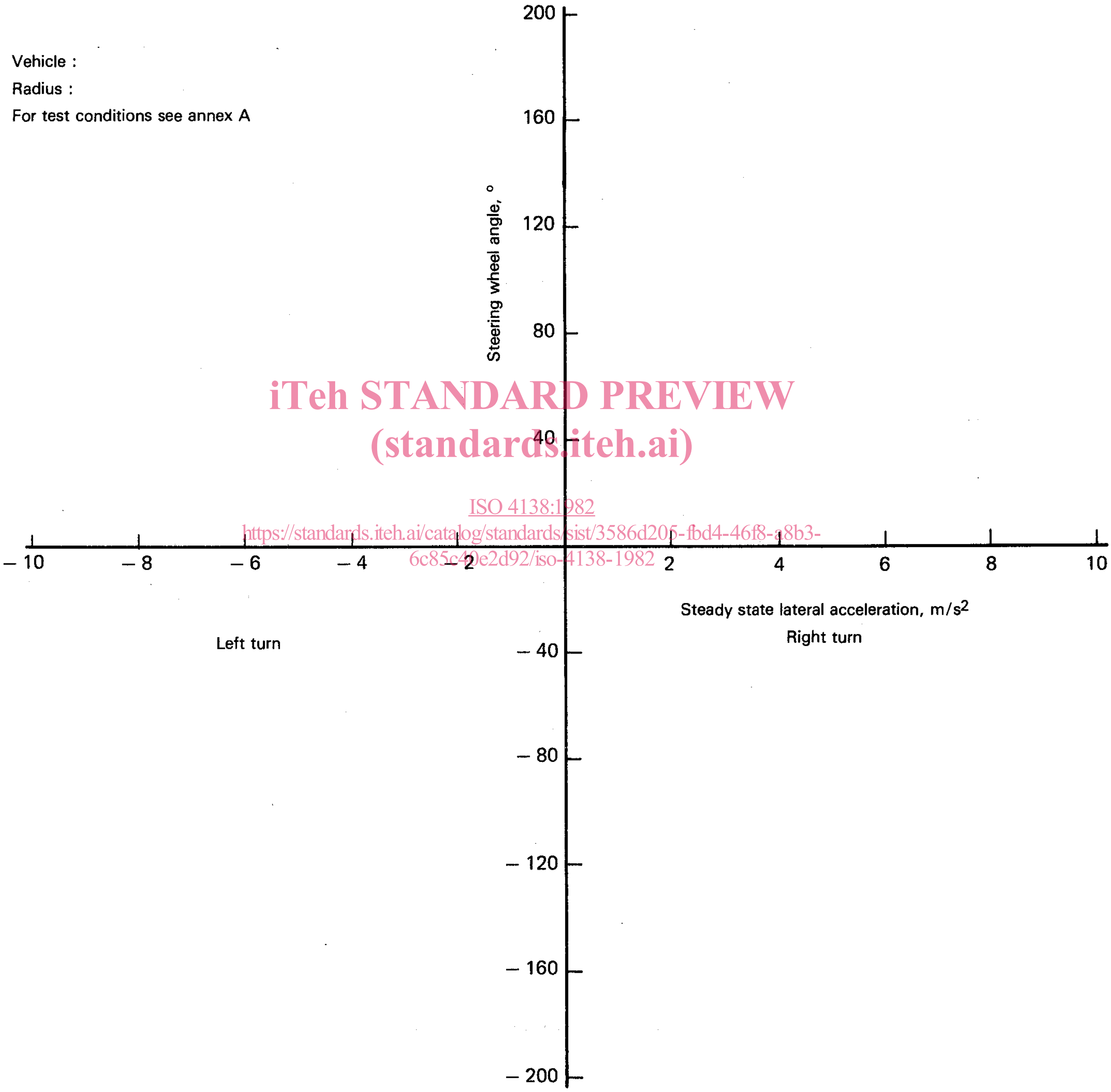

Figure 1 — Steering wheel angle characteristic