Vehicle Weights and Dimensions Study

Volume 7

Investigating Articulated Vehicle Roll Stability
Using a Tilt Table Device
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**Volume 7 -- Investigating Articulated Vehicle Roll Stability Using a Tilt Table Device**

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**Abstract**

The Centre de Recherche Industrielle du Quebec was responsible for the design, construction and testing of a tilt table device capable of assessing the roll stability of long and heavy combination vehicles. The paper describes the design process used in constructing the 80 ft long, 200 000 lb. capacity table, the method of construction and the designed instrumentation and data acquisition capabilities.

The program of testing on the table is discussed, including the procedures used in preparing vehicles for testing, calibration of the instrumentation, data acquisition techniques and method of data analysis. The findings of the program are then reviewed with respect to the influence of various parameter and equipment changes on the roll threshold of tractor semitrailers, including:

a) Costs of Gravity Height
b) Tractor and Semitrailer suspension type
c) Track Width (96" vs 102")
d) Tire Selection (Bias, Radial, Low Profile, Super Single)
e) Fifth Wheel vertical slack

**Keywords**

articulated vehicle stability
overturning (veh) apparatus (measuring rollover

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**Supplementary Information**
DISCLAIMER

This publication is produced under the auspices of the Technical Steering Committee of the Vehicle Weights and Dimensions Study. The points of view expressed herein are exclusively those of the authors and do not necessarily reflect the opinions of the Technical Steering Committee, Canroad Transportation Research Corporation or its supporting agencies.

The test program discussed in this report was carried out using vehicles and components in common usage in the Canadian truck fleet. The tractors, trailers and tires used for testing were provided by the respective manufacturers, and were in brand new condition. The test results observed reflect the conditions of the equipment and test procedures used, and may be expected to vary with equipment which has been used in service, or under different test conditions.

This report has been published for the convenience of individuals or agencies with interests in the subject area. Readers are cautioned that the use and interpretation of the data, material and findings contained herein is done at their own risk. Conclusions drawn from this research, particularly as applied to regulation, should include consideration of the broader context of Vehicle Weights and Dimension issues, some of which have been examined in other elements of the research program and are reported on in other volumes in this series.

The Technical Steering Committee will be considering the findings of these research investigations in preparing its "Final Technical Report" (Volumes 1 & 2), scheduled for completion in December 1986.
PREFACE

The report which follows constitutes one volume in a series of sixteen which have been produced by contract researchers involved in the Vehicle Weights and Dimensions Study. The research procedures and findings contained herein address one or more specific technical objectives in the context of the development of a consistent knowledge base necessary to achieve the overall goal of the study; improved uniformity in interprovincial weight and dimension regulations.

The Centre de Recherche Industrielle du Québec undertook a program of testing on the newly constructed tilt table to examine the static roll stability characteristics of a range of tractor semitrailer configurations. Canroad Transportation Research Corporation gratefully acknowledges the contributions of Transport Canada in providing the tilt table and financial support for the program. In addition, the contributions of the following companies who provided equipment and components for testing purposes are gratefully acknowledged:

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TECHNICAL WORK ELEMENTS OVERVIEW

Weights and Dimensions Study Technical Strategy

- Vehicle Stability and Control Research
  - Computer Simulation
  - Field Testing and Demonstration
- Research Impact Evaluation
  - Load Tests
  - Suspension Effects

- Human Factors
  - Driver Applications

- Vehicle Research
  - Base Line Vehicles
  - State of the Art

Visiting Researcher Program

- Simulation Enhancement
- Simulation Model User's Guide
- Simulation Rover Assessment
- Braking Existing Regulatory Practice
- Braking Hardware Review
Investigating Articulated Vehicle Roll Stability Using a Tilt Table Device

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1.0 INTRODUCTION

1.1 Background

As part of its contribution to the Vehicle Weights and Dimensions study, Transport Canada commissioned the Centre de Recherche Industrielle du Quebec to design and build a tilt table device capable of being used to examine the roll stability characteristics of heavy articulated vehicles. The table was constructed in Montreal and installed at the Transport Canada Motor Vehicle Test Centre in Blainville, Quebec, in the summer of 1985. The tilt table was then made available to Canroad Transportation Research Corporation to conduct a program of testing consistent with the objectives of the Vehicle Weights and Dimensions Study.

1.2 Test Program Objectives

Within the broad scope of the vehicle stability and control research program of the Weights and Dimensions Study, the objectives of the tilt table test program were:

a. To determine the rollover threshold of each of the baseline vehicle configurations being examined by the study, in the loaded condition, to enable a correlation of the dynamic test data with the tilt test results.

b. To provide validation data for the assessment of currently available static rollover models and for the development and/or refinement of a new model.

c. To achieve a verified understanding of the effects of suspension selection on the static rollover threshold of tractor semitrailer combinations.

d. To examine the effects of specific vehicle hardware variations on the rollover threshold.
The testing carried out in pursuit of objective a. is discussed in the final reports on dynamic testing compiled by the Ontario Ministry of Transportation and Communications. The test data required for objective b. was provided to Mr. Jean Bédard of CRIQ in his capacity as Visiting Researcher and is discussed in his final report.

The testing carried out under the latter two objectives is discussed in the report which follows.

1.3 Acknowledgements

Canroad Transportation Research Corporation and the Centre de Recherche Industrielle du Quebec would like to acknowledge the support and assistance provided by the Transport Canada Motor Vehicle Test Centre during the summer and fall of 1985 while the tilt table was employed in this test program.

The generous support and assistance provided by International Harvester (Navistar) Trucks, Manac trailers and Michelin Tires in providing equipment and vehicles for the test program is gratefully recognised.
2.0 TILT TABLE

2.1 Design, Construction and Capabilities

A tilt table is a device used to determine the rollover threshold of heavy vehicles. It is essentially a laterally tilting platform on which vehicles are installed and tilted until one or more high side tires are off the platform. By tilting the vehicle, lateral acceleration is simulated as it is when the vehicle takes a turn at a steady speed. However, in a real situation, when taking a turn, the perpendicular force to the ground remains constant while on the tilt table, it decreases with respect to the tilt angle cosine. Since loaded heavy vehicles tilt at a maximum tilt angle of 25°, the perpendicular force reduction is less than 10%. Consequently, the lateral acceleration simulated by tilting the vehicle on the tilt table remains similar to that in a real situation when turning.

The table is made of two similar sections, each having a modular base and a tilt platform (figures 1 and 2). The modular base is equipped with twelve adjustable supports so it can be leveled to compensate for the uneven pavement. When a vehicle is tilted, the modular base gets an overload on the swivel side; therefore, the structure on this side has been reinforced by adding a longitudinal I-beam. The reaction of the hydraulic cylinders is exerted at two points which are compensated by adjustable supports located on each side of the hydraulic cylinders' resting point.

The tilt platform itself is also made of modules which are simply pivoted with respect to the base by a series of synchronized hydraulic cylinders. The structure of each platform is made of two sets of components which give it longitudinal and transversal stiffness. First, longitudinal stiffness is attained by two important longitudinal elements. On the swivel side, a Z-beam made of two angles welded together is attached to the base by five swivels forming with the
latter a unit extremely resistant to flexion. On the cylinder side, tubes are provided to form a stiff plane that swiches the load from the beams to the cylinders. A series of H-beams are linked transversally to both rigid sides of each platform. This structure remains flexible in torsion in order to prevent excessive stresses if, for any reason, the length of cylinders differ.

The table is designed to be disassembled, transported and re-installed at a new site where the ground is appropriate. For transportation, each section width is reduced to about 4.3 m (14 ft) and the height is less then 3.05 m (10 ft).

The total length of the tilt table is 24.4 m (80 ft); however, the maximum distance between the front and the rearmost axle is limited to 23.75 m (78 ft). The width of the table is 2.9 m (114 in.); so, it takes axle widths ranging from 2.44 to 2.84 m (96 to 112 in.).

The tilt table strength allowed tilting a truck with a gross vehicle weight of 130 000 kg (297 000 lb). However, the load on one particular section must not exceed 67 500 kg (148 500 lb) and the maximum load per axle is limited to 12 000 kg (26 400 lb); there are also some restrictions on load concentration.

The maximum tilt angle is 35° and the operating temperature range is from -18° to 60° C (0° to 140° F). However, the data acquisition equipment must be maintained between 10° and 50° C (50° to 120° F). The table tilt rate is fully adjustable from approximately 15 to 30 degrees per minute. The lowering speed is independently adjustable and varies of 15 degrees or less per minute.

---

1 The maximum load is function of its location on each platform.
FIGURE 3
LOADED AND UNLOADED TILT TEST
There is a set of ramps at each end of the table provided for boarding and disembarking; the maximum slope of these ramps is 10%. The tilt table also incorporates an efficient vehicle restraint system; this system is made of a series of chains which are attached to the platform and to the trailer frame with sufficient slack to enable suspension extensions (figure 3).

The table is operated from a 60 HP-diesel engine (figure 4). The synchronization of hydraulic cylinders is done by using two complementary systems. The main system is a positive displacement flow divider consisting of a series of gear pumps having a common shaft. The divider's exit pressures are normally equal; however, when they differ, the efficiency of the gear pump is quite different and produces uneven flow ranging from 10 to 15%. In such a case, a complimentary system has to be used. This second system is based on the detection of longer cylinders which are automatically drained until their lengths become approximately the same as the others.

At each cycle, at the end of the down stroke, a series of equalizing valves are electrically opened to compensate for any leakage which might have happened during the previous lifting. The controls also include a series of switches to make sure that each section of the table remains leveled and synchronized with the other.

An alarm is triggered by the switches telling the operator that the correction system cannot keep the two platforms at sufficient required leveling. However, when the load is well distributed over the two platforms, the pressure in all hydraulic cylinders is the same and the leveling correction is then seldom made. That condition corresponds to the ideal and desired operating condition.

Note: There is an operation and maintenance manual available for the tilt table.
FIGURE 4

HYDRAULIC GROUP
FIGURE 6.
LOAD ARRANGEMENT
2.2 Instrumentation and Data Acquisition

The tilt table has five weight-measuring pads which can be moved to accommodate the various axle distributions. Each weighing pad contains four load cells which are temperature compensated and located at each corner of the pad. The four load cells were installed in order to measure the perpendicular forces to the ground only. The pads are provided with longitudinal and transversal reaction rods which insulate the load cells from longitudinal and lateral forces. The figure below illustrates a load cell installation.

The side of the pads are raised to prevent tires from sliding during a tilt test; it also gives the pad a good longitudinal stiffness.

The pad is 3.35 m (11 ft) long and 107 cm (42 in.) wide. The total capacity of each weighing pad is 45 455 kg (100 000 lb) i.e. 11 364 kg (25 000 lb) for each load cell. However, the maximum perpendicular load that one vehicle axle may exert on a weighing pad is limited to 22 727 kg (50 000 lb). The pads can be positioned on either side of the tilt table. The spaces between the weighing pads are filled with a series of wood blocks which form a solid surface.

The tilt angle is measured in two different ways:

- a pendulum-type tilt angle indicator is mounted on a tilting platform and it gives the operator a quick estimate of the angle the table has reached;
a precision tilt sensor is installed on one platform and supplies the data acquisition system with a signal proportional to the tilt angle.

The precision of all the measurements coming from the load cells and the tilt sensor is ±1% of full scale. During a tilt test, the data acquisition system controlled by a micro-processor reads and displays the tilt angle and the corresponding loads on each weighing pad at regular time intervals. All readings are displayed and recorded in SI units.
3.0 TEST PROCEDURES

The tests conducted in this study were divided as follows:

- Test Series One: Influence of Center of Gravity Height
- Test Series Two: Influence of Tractor Suspension Selection
- Test Series Three: Influence of Track Width
- Test Series Four: Influence of Tire Choice
- Test Series Five: Influence of Fifth Wheel Vertical Slack

3.1 Vehicle Preparation and Setup

The vehicle basic configuration determined the way of positioning each vehicle and each weighing pad on the platform (figure 5); however, the last trailer axle was always located at the same place.

Tires on the low side were blocked with 2 x 4 in. lumber placed flat along the pad sides to make sure that no side slipping would take place during tilting. It was felt that 2 x 4 in. blocks would not interfere with the normal deflection of the tires because the 1 1/2 inch height of the blocks extended only to the depth of the tire tread. For loaded condition tests, concrete blocks of 2 x 3 x 4 feet weighing between 1364 and 1455 kg (3000 to 3200 lb) were placed at the position corresponding to the double drive axle and the double trailer axle center within ± 1 inch (figure 6). The total load including the axle load was 16 000 kg (35 200 lb) on each position. The load was secured by straps and chains.
FIGURE 5: VEHICLES AND WEIGHING PADS POSITION
FIGURE 6
LOAD ARRANGEMENT
Tire pressure was checked and set at 100 psi before each test.

Inclinometers were installed at the following positions (figure 7):

- front of tractor (bumper)
- back of trailer frame
- front of trailer (deck)
- back of trailer (deck)
- longitudinal axis of trailer (for deck angle)

An inclinometer was also installed on each section of the table to monitor the tilt angle of each section and to supplement the permanently installed inclinometer on the table.

Specifications of each vehicle were measured and catalogued for tested including:

- tractor and trailer type
- tractor and trailer length
- tractor and trailer tire type
- tractor and trailer suspension type
- tractor and trailer axle spread
- tractor and trailer track width
- tire pressures
- fifth wheel height
FIGURE 7
LOCATION OF THE INCLINOMETERS
The ambient air temperature during the test was also noted. Each vehicle was also secured to the table with its restraint system. The tractor engine was started to get the normal operating pressure in air system and all brake systems were released for the tilt test.

For tractor and trailer having air suspension, test were conducted with height control valve installed and operating and the tractor engine was running during the tilt test procedure.

### 3.2 Instrumentation and Data Acquisition

The instrumentation used for the test program included the following:

- **Tilt table instrumentation:**
  - axle load measuring pad
  - tilt table angle sensor
  - 2 inclinometers

- **Vehicle instrumentation:**
  - 5 inclinometers

Instrumentation calibration and specifications are included in Appendix 2.

The data acquisition system consisted of:
- Hewlett Packard 9816 Computer
- HP 3497A Data Logger
- HP 44421A Input Voltage Card
- HP 44427B Input Strain Card
- HP 82906A Printer

The output signal of pad load cells were connected by a cable to the data acquisition system; the exciting voltage was 10 VDC. The zero balance of each pad was made including the pad weight. The inclinometers and tilt sensor exciting voltage were 10 VDC and they were connected to the data acquisition system.

Data was recorded every four seconds during each tilt test. It was handled and computerized and printed on graphs and tables.
3.3 Data Reduction and Analysis

- Calculation of center of gravity height

The center of gravity height was calculated according to the following procedure.

Suppose an axle which supports a load $W$ and which has no relation with the other axles.

Then at equilibrium

$$\Sigma F_H = 0$$
$$\Sigma F_V = P_1 + P_2 = 0$$

By measuring $P_1$ and $P_2$, it is possible to determine:

$$W = P_1^0 + P_2^0$$
$$B = \frac{P_1^0 \times L}{P_1^0 + P_2^0} = \frac{P_1^0 L}{W}$$

If this body is tilted with respect to the horizontal by an angle $\theta$ and assuming that the reactions to the ground remain at the same place, it is possible to resolve that:

$$\Sigma F_H = W \sin \theta - P_1 - P_2 = 0$$
$$\Sigma F_V = P_1' + P_2' - W \cos \theta = 0$$

$$\Sigma F_2' = W \times D - P_1 \times L = 0$$

then $P_1 + P_2 = W \sin \theta$

$$D = \frac{P_1' \times L}{W} = \frac{P_1' \times L}{P_1^0 + P_2^0}$$
\[ H \tan \theta + \frac{D}{\cos \theta} = B \]
\[ H \sin \theta + D = B \cos \theta \]
\[ H = B \cot \theta - D \csc \theta \]
\[ H = \frac{P_1^0 \times L}{P_1^0 + P_2^0 \tan \theta} - \frac{P_1^0 \times L}{P_1^0 + P_2^0 \sin \theta} \]
\[ H = \frac{L}{(P_1^0 + P_2^0) \sin \theta} [P_1^0 \cos \theta - P_1^0] \]

**if**
- \( H \): center of gravity height
- \( L \): axle spread of the trailer
- \( W \): total axle load
- \( P_1^0 \): load applied to the high side reaction at \( \theta = 0^\circ \)
- \( P_1 \): load applied to the high side reaction at \( \theta = \theta \)
- \( B \): lateral position of the C of G measured with respect to \( P_2 \)
- \( \theta \): tilt angle

**This formula was chosen instead of the following:**

\[ H = -\frac{L}{W} \frac{P_1^0}{\tan \theta} + \frac{1}{\cos \theta} \frac{3P_1}{36} \]
\[ H = -\frac{L}{W} \left[ \frac{3P_1}{36} \right] \theta = 0 \]
\[ H = \frac{1}{W \cos \theta} \left[ \frac{b}{36} \frac{aP_2 - (L - B)}{36} \frac{aP_1}{36} \right] \]
because the center of gravity height is determined by load transfer while other formulas use the transfer rate which is obtained by the derivation of the load with respect to the angle $\theta$. Moreover, the chosen formula takes into account the fact that the load may not be equally distributed between $P_1$ and $P_2$. For this study, all the center of gravity heights were calculated for an angle $\theta$ ranging from 4 to 5°.

- Correction of Data for Load Pad Weight

The load pads were designed in such a way that the load cells support most of the pad weight; moreover, the normal component to the surface of the table is the only component read by the load cells. Since the zero balance of the load cells is adjustable, it is therefore possible to eliminate the initial weight of the pad; however, when the table is tilted, a correction has to be made in order to take into account the reduction of the normal component of the pad weight. Then, to get the correct load value of the load pad, the following formula—which includes the correction factor—has to be used:

$$P_C = P + W (1 - \cos \theta)$$

if $P_C$: corrected load value
$P$: load at a tilt angle
$W$: pad weight estimated at 909 kg
$\theta$: tilt angle

This correction factor was used to plot all graphs.

- Determination of Rollover Threshold

The rollover threshold was determined for loaded and unloaded vehicles in Phases II and III and only for loaded vehicles in Phase I which are all described in section 3.1. The criterion established to define
the rollover threshold was the following: rollover could be assumed to occur when one or more sets of tires on the high side of the trailer reach zero loading or come off the platform.
4.0 SUMMARY OF FINDINGS

Introduction

The tilt test program was designed to examine the influence of specific variations on loading, parameters and equipment on the static rollover threshold of combination vehicles. To the extent possible, all factors except those under examination were controlled from one test configuration or vehicle to the next. Efforts were taken to obtain tractors and trailers with the same physical dimensions and components, new tires were installed on all tractor and trailer axles and inflated to the same pressure, and a standard vehicle preparation and test procedure was maintained throughout the program.

There are, however, minor variations between vehicles, accuracy limitations on test instrumentation, and limitations inherent in the test procedure itself which must be recognised and reviewing and interpreting the results. Examples of these types of factors include:

a. each test vehicle combination was tilt tested only once, from left to right when facing forward;

b. tractor wheelbases and axle spreads varied slightly between vehicles;

c. there were two types of fifth wheels installed on the five tractors employed in the program, although both types were physically similar and equivalent capacity rated.

However, as the objective of the program was to examine and identify those factors which significantly affect the static roll threshold of combination vehicles, any inconsistencies introduced by factors such as those above were deemed to be minor, in relative terms.
Presentation of Results

The tilt test procedure and data acquisition techniques were described in previous sections. For each tilt test conducted, time histories of the following data elements were collected:

a. the inclination angle of the tilt table, measured at three locations along its length;

b. the inclination angle of the tractor chassis (front and rear);

c. the inclination angle of the trailer deck (front and rear);

d. the loads on the high and low sides of the trailer axle group;

e. the loads on the high and low sides of the tractor drive axle group;

f. the load on the high side of the tractor steering axle;

g. the horizontal inclination (pitch) of the trailer deck.

In total, 51 tilt tests were conducted and are summarized graphically in Appendix 3.

Establishment of Static Roll Threshold

In all cases, the load on the high side of the trailer axle group reached zero first. The inclination angle of the tilt table at which this occurred was determined graphically by plotting the normalized high side load on the trailer axles against the inclination angle of the table. The normalized loading was calculated by dividing the loading on the high side of the trailer axles at a given table angle by the initial
high side loading when the table was horizontal. This ratio provides a consistent depiction of the load reduction on the axle group (from 1 to 0) thereby facilitating comparison of the performance of one vehicle combination with the next.

The tangent of the angle of the table at which zero loading occurred is equal to the amount of lateral acceleration the vehicle would be sustaining if negotiating a curve under steady state conditions. This was calculated for each tilt test discussed in the following sections and serves as the basis for comparison of roll thresholds.

4.1 Test Series One: Influence of Centre of Gravity Height

Two similarly equipped five axle tractor semitrailers were prepared for the tilt test to illustrate the influence of centre of gravity height on the static roll threshold. In one case, the vehicle was loaded to obtain a centre of gravity of 60 inches, in the second case, the loading resulted in a centre of gravity height at 84 inches.

The results of the tests are plotted in Figure 8 and can be summarized as follows:

<table>
<thead>
<tr>
<th>Combination</th>
<th>C of G Height</th>
<th>Tilt Angle at Wheel Lift</th>
<th>Lateral Acceleration</th>
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<tr>
<td></td>
<td>Calculated</td>
<td>Measured</td>
<td>Calculated</td>
</tr>
<tr>
<td>Combination 1</td>
<td>1.52 m (60 in.)</td>
<td>28.5 degrees</td>
<td>0.54 g</td>
</tr>
<tr>
<td>Combination 2</td>
<td>2.13 m (84 in.)</td>
<td>19.3 degrees</td>
<td>0.35 g</td>
</tr>
<tr>
<td>% Change</td>
<td>+40%</td>
<td></td>
<td>-35%</td>
</tr>
</tbody>
</table>
Observations

It is evident from this test that the centre of gravity height is an important variable affecting combination vehicle roll stability. It has been noted in previous research (1) that a 100 mm reduction in centre of gravity height will generally improve the vehicle’s static roll threshold by 0.03 g. This is supported by the above results.

In some jurisdictions consideration is being given to imposing a roll stability standard for heavy vehicles. If, for example, a minimum capability of sustaining 0.4 g lateral acceleration were considered, the vehicles tested in this program would require the centre of gravity height to be less than 1.70 m (67 inches) to achieve this performance.

4.2 Test Series Two: Influence of Suspension Selection

The objective of this series of tilt tests was to examine the effect of different tractor and trailer suspension types on the static roll threshold of the five axle tractor semi-trailer combination. A program of testing was designed which would isolate the influence of a change in either tractor or trailer suspension on the static roll threshold of the combination, while keeping other factors, such as centre of gravity height, constant. A selection of four tractor and three trailer suspension types was made on the basis of those identified as being in most common usage in the Canadian interprovincial trucking fleet or which constituted generically different design concepts.

Four new, dimensionally similar tractors were obtained from International Harvester (Navistar) with the following tandem drive axle suspensions:
a. Walking Beam - Hendrickson RTE 440 (44 000 lb rating)
b. Air - Neway ARD 244 (44 000 lb rating)
c. Air - IH Air (38 000 lb rating)
d. Spring - IH 4 Spring (38 000 rating)

Three new, 48 foot long tandem axle flatbed trailers were provided by Manac Trailers, equipped with the following tandem axle suspensions:

a. Walking Beam - Chalmers 700
b. Air - Neway AR95 - 17
c. Spring - Reyco 21B

Test Procedure

The four tractors and three trailers obtained for the program provided 12 combinations of tractor and trailer suspension couplings. In carrying out the test sequence, one tractor-semi-trailer combination was prepared for testing, a standard number of concrete ballast blocks were loaded in predetermined locations to obtain the required axle loadings and centre of gravity height, and a tilt test was carried out. The tractor was then removed and substituted with another with a different drive axle suspension. The tilt test was then repeated without adjusting the loading condition of the trailer. Similarly, the third tractor was then substituted and the test conducted once more.

The test conditions for all combinations were as follows:

- Tractor tandem drive axle load was 16 000 kg (35 200 lb)
- Trailer tandem axle group load was 16 000 kg (35 200 lb)
- Tractor fifth wheels were located midway between the two drive axles.
- The centre of gravity height was calculated to be approximately 2.13 m (84 inches). While there is some uncertainty as to the accuracy of the estimated C of G height obtained through this calculation, it is assumed that with dimensionally identical trailers loaded in the same manner with the same concrete blocks, the C of G was held virtually constant throughout the program.
4.2.1 Influence of Tractor Drive Axle Suspensions

Figures 9, 10 and 11 depict the influence of the four tractor drive axle suspensions on the static roll threshold of the combination vehicle which results when the trailer and loading are held constant. In summary, the results of this test sequence were as follows:

| TABLE I |
|-----------------|--------|--------|--------|
| TRACTOR         | CHALMERS | REYCO  | NEWAY  |
| Hendrickson     | 0.34 g   | 0.35 g | 0.36 g |
| IH 4 Spring     | 0.31 g   | 0.33 g | 0.35 g |
| Neway           | 0.31 g   | 0.33 g | 0.32 g |
| IH Air          | 0.32 g   | 0.34 g | 0.34 g |
| % Variation     | 10.0%    | 8.3%   | 10.2%  |

Observations

The tractor drive axle suspension plays a significant role in the roll stability of combination vehicles. As can be seen from the preceding tilt test results, the static roll threshold of a tractor semitrailer configuration can be improved or reduced by up to 10% through the choice of tractor suspension for a given trailer suspension. Using the findings of the previous section, it is evident that the substitution of a less roll stable tractor drive suspension for a given trailer could have potentially the same effect as increasing the centre of gravity of the combination 100 mm (4 inches).
Test Series 2: Influence of Tractor Suspension Selection

Neway Trailer with:
- Neway Tractor
- Hendrickson Tractor
- IH Air Tractor
- IH 4 Springs Tractor

P of G=64

Normalized Tractor Axle Group Load (High Side)

Tilt Table Angle (θ)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Test Series 2: Influence of Tractor Suspension Selection

Reyco Trailer with:
- Neway Tractor
- Hendrickson Tractor
- IH Air Tractor
- IH 4 Springs Tractor

Tilt Table Angle (°)
Tractor Drive Axle Suspension Roll Stiffness

The difference between the inclination angle of the tilt table and the inclination angle of the rear of the tractor chassis as the vehicle progresses through the tilt sequence until wheel lift off provides valuable insight to the resistance to roll provided by the tractor's drive axle suspension for each of the four suspension types tested, the average (over three tests) inclination angle of the rear of the tractor chassis is plotted against the tilt table angle in Figure 12.

The relative roll stiffnesses of the four suspensions as depicted in this figure can be compared as follows:

<table>
<thead>
<tr>
<th>TRACTOR SUSPENSION</th>
<th>TILT TABLE ANGLE</th>
<th>TRACTOR CHASIS (REAR) INCLINATION RELATIVE TO TILT TABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hendrickson</td>
<td>8 degrees, 16 degrees</td>
<td>0.8 degree, 4.1 degrees</td>
</tr>
<tr>
<td>IH 4 Spring</td>
<td>8 degrees, 16 degrees</td>
<td>1.4 degree, 6.4 degrees</td>
</tr>
<tr>
<td>Neway Air</td>
<td>8 degrees, 16 degrees</td>
<td>3.4 degree, 8.3 degrees</td>
</tr>
<tr>
<td>TH Air</td>
<td>8 degrees, 16 degrees</td>
<td>3.8 degree, 8.5 degrees</td>
</tr>
</tbody>
</table>

From the preceding Table it can be seen that the resistance to roll offered by the four different suspension systems varies significantly. The Hendrickson (walking beam) suspension had permitted the tractor chassis to rotate 0.8 degree relative to the tilt table when the table was inclined at 8 degrees. Under the same conditions, the IH 4 spring suspension allowed 1.4 degree of rotation and the two air suspensions permitted rotations of 3.4 and 3.8 degrees.
Figure 12: Tractor Drive Axle Suspension Roll Stiffness

- Hendrickson Tractor
- Neway Tractor
- IH 4-Springe Tractor
- IH Air Tractor

Tractor Chassis Rotation Relative to Tilt Table Degrees

Tilt Table Angle (θ₁)
At a tilt table angle of 16 degrees, just prior to trailer wheel lift off, the walking beam suspension allowed 4.1 degrees of chassis rotation, the 4 Spring allowed 50% more at 6.4 degrees, and both air suspensions 100% more or over 8 degrees.

In the previous section, it was noted that the tractor drive axle suspension plays a significant role in the roll stability of combination vehicles. The variation in resistance to roll provided by the different suspension systems, as depicted in Figure 12, provides insight to the reasons why the range in static roll thresholds was observed.

4.2.2 Influence of Trailer Tandem Axle Suspensions

Using the test results obtained in the preceding sequence, and focussing on the effect on tractor semitrailer roll stability due to trailer suspension substitution, the results are replotted in Figures 13 to 16. In summary, the static roll thresholds obtained through testing were as follows:

**TABLE 2**

<table>
<thead>
<tr>
<th>TRAILER</th>
<th>TRACTOR DRIVE AXLE SUSPENSION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HENDRICKSON</td>
</tr>
<tr>
<td>Chalmers</td>
<td>0.34 g</td>
</tr>
<tr>
<td>Reyco</td>
<td>0.35 g</td>
</tr>
<tr>
<td>Neway</td>
<td>0.36 g</td>
</tr>
<tr>
<td>% variation</td>
<td>5.8%</td>
</tr>
</tbody>
</table>
Figure 15: Test Series 2: Influence of Trailer Suspension Selection

IH 4 Springs Tractor with:
- Rayco Trailer
- Neway Trailer
- Chalmers Trailer
C of G = 84
Figure 14: Test Series 2: Influence of trailer suspension selection

- Hendrickson Tractor with:
  - Reyco Trailer
  - Navco Trailer
  - Chalmers Trailer

Tilt Table Angle ($\theta$)
Test Series 2: Influence of Trailer Suspension Selection

IH Air Tractor with:
  - Rayco Trailer
  - Neway Trailer
  - Chalmers Trailer
  - C of C=84"
Observations

With the exception of the results obtained for the IH 4 Spring tractor, the influence of the trailer suspension on the combination's static roll threshold appears to be less significant than the contribution of the tractor drive suspension. As can be seen in the preceding table, the variation on roll threshold due to trailer suspension variation appears to be in the order of 5%. The 15% variation observed for the IH 4 Spring suspension appears to be inconsistent, however, no experimental or procedural errors were identified which would place these findings in question.

Trailer Suspension Roll Stiffness

The range of roll stability performance observed for the three suspension types tested is a reflection of the variation in their roll stiffness characteristics. By plotting the inclination angle of the rear of the trailer deck relative to the inclination angle of the tilt table, insight is gained to the behaviour of each of the suspension types as the trailer progresses through the tilt to wheel lift off. Figure 17 presents the average (based on four tilt tests) trailer deck rotation relative to the table for each of the three trailer suspensions.

In summary, the relative roll stiffness of these suspensions are as follows:
Figure 17: Trailer Suspension Roll Stiffness

- Reyco Trailer
- Newco Trailer
- Chalmers Trailer

Tilt Table Angle ($\theta$)
<table>
<thead>
<tr>
<th>TRACTOR SUSPENSION</th>
<th>TILT TABLE ANGLE</th>
<th>TRACTOR CHASSIS (REAR) INCLINATION RELATIVE TO TILT TABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chalmers</td>
<td>8 degrees, 16 degrees</td>
<td>1.9 degree, 7.0 degrees</td>
</tr>
<tr>
<td>Reyco</td>
<td>8 degrees, 16 degrees</td>
<td>1.2 degree, 4.2 degrees</td>
</tr>
<tr>
<td>Neway</td>
<td>8 degrees, 16 degrees</td>
<td>0.7 degree, 1.8 degree</td>
</tr>
</tbody>
</table>

The resistance to roll offered by each of these suspensions through the range of table rotation demonstrates the different design characteristics of each.

The Neway Air suspension was by far the stiffest of the three tested, and showed no abrupt changes in the roll stiffness provided from 2 to 16 degrees of table inclination.

The Reyco 4 Spring suspension was the second stiffest, but during the transition in table angle from 12 to 14 degrees, trailer deck rotation increased rapidly, as spring lash occurred.

The Chalmers suspension permitted the most trailer deck rotation to occur through the range of table angle, and also demonstrated an abrupt decrease in resistance to roll when the table angle reached 10 degrees. During the progression from 10 degrees of table inclination to 16 degrees, the Chalmers suspension permitted 0.8 degree of trailer deck rotation for every increase of 1 degree in table angle. This compares with 0.05 degree/degree for the Neway suspension over the same interval.
4.2.3 Summary of Findings - Suspension Variation

The static roll thresholds for the twelve combinations of tractor and trailer suspension matches tested rank as follows (from highest to lowest):

<table>
<thead>
<tr>
<th>TRACTOR SUSPENSION</th>
<th>TRAILER SUSPENSION</th>
<th>TABLE ANGLE AT WHEEL LIFT</th>
<th>LATERAL ACCELERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hendrickson</td>
<td>Neway</td>
<td>19.7</td>
<td>0.36</td>
</tr>
<tr>
<td>Hendrickson</td>
<td>Reyco</td>
<td>19.5</td>
<td>0.35</td>
</tr>
<tr>
<td>IH 4 Spring</td>
<td>Neway</td>
<td>19.1</td>
<td>0.35</td>
</tr>
<tr>
<td>IH Air</td>
<td>Neway</td>
<td>18.8</td>
<td>0.34</td>
</tr>
<tr>
<td>IH Air</td>
<td>Reyco</td>
<td>18.8</td>
<td>0.34</td>
</tr>
<tr>
<td>Hendrickson</td>
<td>Chalmers</td>
<td>18.7</td>
<td>0.34</td>
</tr>
<tr>
<td>Neway</td>
<td>Reyco</td>
<td>18.3</td>
<td>0.33</td>
</tr>
<tr>
<td>IH 4 Spring</td>
<td>Reyco</td>
<td>18.1</td>
<td>0.33</td>
</tr>
<tr>
<td>Neway</td>
<td>Neway</td>
<td>18.0</td>
<td>0.32</td>
</tr>
<tr>
<td>IH Air</td>
<td>Chalmers</td>
<td>18.0</td>
<td>0.32</td>
</tr>
<tr>
<td>IH 4 Spring</td>
<td>Chalmers</td>
<td>17.1</td>
<td>0.31</td>
</tr>
<tr>
<td>Neway</td>
<td>Chalmers</td>
<td>17.1</td>
<td>0.31</td>
</tr>
</tbody>
</table>

The above ranking is based on a limited test program which employed only single examples of each suspension type under examination. All equipment tested was of current manufacture and was in new condition. Undoubtedly, the static roll thresholds of these suspension couplings will vary with the condition of the components, the torsional rigidity of the trailer, the type and condition of the fifth wheel and kingpin and numerous other factors. However, the range of performance demonstrated above is significant and underlines the implications on the roll stability of combination vehicles which could be attributed to tractor and trailer suspensions as variables in daily fleet operation.
Summary Observations:

1. The resistance to roll offered by both tractor and trailer suspensions appears to be the most influential suspension characteristic affecting the roll stability of the vehicle combination.

2. The choice of tractor drive axle suspension appears to have a greater influence (10%) on the roll threshold of the vehicle combination than the choice of trailer suspension (5%).

3. The generic suspension design does not appear to be necessarily related to suspension roll stiffness. For example, the air suspension tested on the trailer provided the greatest roll resistance, while on the tractor, air suspensions exhibited the least roll stiffness.

4.3 Test Series Three: Influence of Trailer Axle Width

Trailer axles have been available in Canada for several years in two lengths to provide nominal widths across the tires of either 96 inches or 102 inches. The objective of this test series was to examine the influence of axle width, at these two points, on the static roll threshold of the tractor semitrailer configuration.

Two new 48 foot flatbed semi-trailers were provided by Manac trailers for testing which were both equipped with Reyco 218 4 Spring suspensions. One of the trailers was fitted with the narrower axles providing an overall width across the tires of 92.5 inches (dual tires). The second trailer was equipped with the wider axles, and relocated spring centres, providing an overall width across the tires of 99 inches. Both trailer were prepared and loaded in a similar manner coupled in turn to a tractor fitted with a IH 4 Spring suspension on a 96 inch nominal track width, and tilt tested in the standard manner.
Case 1: Dual Tires

Both trailers were fitted with new Michelin 11R 22.5 XZA radial tires, inflated to 100 psi and were loaded to obtain a centre of gravity height of approximately 84 inch. The results of this test sequence are depicted in Figure 18 and are summarized as follows:

<table>
<thead>
<tr>
<th>TRAILER TRACK WIDTH (NOMINAL)</th>
<th>WIDTH ACROSS TIRES (ACTUAL)</th>
<th>TABLE ANGLE AT WHEEL LIFT</th>
<th>LATERAL ACCELERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>96 in. (2.44 m)</td>
<td>92.5 in (2.35 m)</td>
<td>17.9 degrees</td>
<td>0.32 g</td>
</tr>
<tr>
<td>102 in. (2.59 m)</td>
<td>99.0 in (2.51 m)</td>
<td>19.1 degrees</td>
<td>0.35 g</td>
</tr>
<tr>
<td>% Change</td>
<td>+ 7.0%</td>
<td></td>
<td>+ 7.2%</td>
</tr>
</tbody>
</table>

Observations:

It is evident from the above that when all other factors are held constant, such as centre of gravity height, the increase in nominal track width from 96 inches to 102 inches provided a 7% improvement in the static roll threshold of the tractor semitrailer combination.

Case 2: Wide Base Single Tires

The standard radial tires were removed from both trailers and replaced with Michelin 16.5R 22.5 wide base single tires (two per axle). The tractor tires were not changed from duals to singles in this test sequence. The tilt tests were repeated with the same loading conditions as in Case 1. The test results are plotted in Figure 19 and are summarized as follows:
Test Series 3:
Influence of Track Width-Wide Base Single Tires

IH 4 Spring Tractor
- 96' Rayco Trailer with Michelin Super Single
  16.5R 22.5 XM+64
- 102' Rayco Trailer with Michelin Super Single
  16.5R 22.5 XM+64
C of C = 64

Normalized Tractor-Axle Group Load Distribution

Tilt Table Angle ($\phi$)
<table>
<thead>
<tr>
<th>TRAILER TRACK WIDTH (NOMINAL)</th>
<th>WIDTH ACROSS TIRES (ACTUAL)</th>
<th>TABLE ANGLE AT WHEEL LIFT</th>
<th>LATERAL ACCELERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>96 in. (2.44 m)</td>
<td>92.5 in (2.35 m)</td>
<td>18.4 degrees</td>
<td>0.33 g</td>
</tr>
<tr>
<td>102 in. (2.59 m)</td>
<td>99.0 in (2.51 m)</td>
<td>20.3 degrees</td>
<td>0.37 g</td>
</tr>
<tr>
<td>% Change</td>
<td>+ 7.0%</td>
<td></td>
<td>+ 11.2%</td>
</tr>
</tbody>
</table>

Observations:

When fitted with wide base single tires on the trailer only, increasing the nominal track width from 96 inches to 102 inches improved the static roll threshold of the combination vehicle 11.2% in the tilt test.

4.4 Test Series Four - Influence of Tire Selection

The objective of this test series was to examine the influence of tire type and construction on the static roll threshold of the tractor trailer combination. The two trailers equipped with axles providing nominal track widths of 96 inches and 102 inches were both used in this sequence, coupled to the tractor fitted with the IH 4 Spring suspension. The loading condition of the trailers was maintained as in previous tests, with a centre of gravity height at an estimated 84 inches. The tires on the tractor were not varied.

The results of this test series are plotted in Figure 20 for the nominal 96 inch track width, and in Figure 21 for the nominal 102 inch track width. In summary, the results were as follows:
Test Series 4:
Influence of Tire Choice-96" Nominal Track Width

- Bire Good Year Hi-Miler
  10.00-20

- Michelin Radial
  VR 22.5 XZA

- Michelin Low Profile
  275/80R 22.5 Pilot Sports XA

- Michelin Super Single
  16.5R 22.5 XM-S4

Normalized Tractor Axle Group Load (H/L Ratio)

Tilt Trolley Angle (°)
Test Series A:

Influence of Tire Choice - 1D2: Nominal Track Width

- Bias Good Year Hi-Miler 10.00-20
- Michelin radial 11R 22.5 XZA
- Michelin Low Profile 275/80R 22.5 Pilot XA
- Michelin Super Single 16.5R 22.5 XR+64

Normalized Trolley Axle Group Load (High Side)

Tilt Table Angle (θ1)
**TIRE TYPE VARIATION: SUMMARY OF TILT TEST RESULTS**

Tractor Suspension: IH 4 Spring  
Trailer Suspension: Reyco 21B

<table>
<thead>
<tr>
<th>Case 1: 96 inch track</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRAILER TIRE TYPE</strong></td>
<td><strong>TRAILER TIRE SIZE</strong></td>
<td><strong>WIDTH ACROSS TIRES</strong></td>
<td><strong>TABLE ANGLE AT WHEEL LIFT</strong></td>
<td><strong>LATERAL ACCELERATION (calculated)</strong></td>
</tr>
<tr>
<td>Goodyear Hi-Miler</td>
<td>Bias Ply</td>
<td>10.00 - 20</td>
<td>95.0</td>
<td>18.1</td>
</tr>
<tr>
<td>Michelin XZA</td>
<td>Radial</td>
<td>11R 22.5</td>
<td>95.0</td>
<td>17.8</td>
</tr>
<tr>
<td>Michelin Pilote XA</td>
<td>Low Profile</td>
<td>275/80R 22.5</td>
<td>95.0</td>
<td>17.9</td>
</tr>
<tr>
<td>Michelin XM+54</td>
<td>Super Single</td>
<td>16.5R 22.5</td>
<td>92.5</td>
<td>18.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case 2: 102 inch track</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRAILER TIRE TYPE</strong></td>
<td><strong>TRAILER TIRE SIZE</strong></td>
<td><strong>WIDTH ACROSS TIRES</strong></td>
<td><strong>TABLE ANGLE AT WHEEL LIFT</strong></td>
<td><strong>LATERAL ACCELERATION (calculated)</strong></td>
</tr>
<tr>
<td>Goodyear Hi-Miler</td>
<td>Bias Ply</td>
<td>10.00 - 20</td>
<td>100.0</td>
<td>19.5</td>
</tr>
<tr>
<td>Michelin XZA</td>
<td>Radial</td>
<td>11R 22.5</td>
<td>100.0</td>
<td>19.1</td>
</tr>
<tr>
<td>Michelin Pilote XA</td>
<td>Low Profile</td>
<td>275/80R 22.5</td>
<td>100.0</td>
<td>19.5</td>
</tr>
<tr>
<td>Michelin XM+54</td>
<td>Super Single</td>
<td>16.5R 22.5</td>
<td>97.5</td>
<td>20.3</td>
</tr>
</tbody>
</table>

**Observations:**

On a nominal 96 inch and 102 inch track widths, the influence of tire type on the roll threshold of the tractor semitrailer appears to be too small to be discussed on the basis of the tilt test results. The improvement in roll threshold due to substitution of wide base single tires is probably a reflection of the effective increase in track width over dual tires, and not likely attributable to tire characteristics.
4.5 Test Series Five: Influence of Fifth Wheel Vertical Slack

Fifth wheel and kingpin designs used in the current trucking fleet allow virtually universal connection of any tractor with any trailer. As a consequence, the dimensions of fifth wheels and kingpins are established with the need for flexible application in mind. The length of the kingpin often exceeds the depth of the mouth of the fifth wheel, thereby permitting the trailer to be lifted vertically off the fifth wheel to the extent of the additional kingpin length, while coupled. This "vertical slack" could potentially be in the range of 1/2 to 1 inch.

The roll stability provided to the semi-trailer by the tractor passes through the fifth wheel coupling. When vertical slack is present in the fifth wheel/kingpin linkage, the trailer will be permitted to rotate around the fifth wheel until this slack is removed and the roll moment begins to be transmitted through the coupling.

The objective of this tilt test series was to examine the influence of this vertical slack on the overall roll threshold of the tractor semi-trailer combination. A tractor fitted with an IH 4 Spring suspension was coupled to a 48 foot long flatbed semitrailer loaded in the standard manner described previously. The combination was tilt tested without modification to the fifth wheel. Shims (figure 22) were then placed between the fifth wheel and the trailer mounting plate to remove one half of the slack present, and the test was repeated. Finally, shims were installed to remove all remaining slack and the test repeated again.

The results of these three tilt test are plotted in Figure 23 and are summarized as follows:
FIGURE 22
FIFTH WHEEL ADJUSTMENT
Test Series 9: Influence of Fifth Wheel Vertical Slack

- IH-4 Springs Tractor
- Reyco Trailer
- Full Slack
- Half Slack
- None
- C of G=84°

Normalized Tractor Axle Group Load (High Scale)

Table Angle (°)
Tractor Suspension: IH 4 Spring
Trailer Suspension: Reyco 21B
Fifth Wheel: Fontaine

<table>
<thead>
<tr>
<th>TABLE ANGLE AT WHEEL LIFT</th>
<th>LATERAL ACCELERATION</th>
<th>% CHANGE FROM NORMAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>degrees</td>
<td>g</td>
<td>%</td>
</tr>
<tr>
<td>Normal Slack present</td>
<td>17.9</td>
<td>0.32</td>
</tr>
<tr>
<td>Half Slack Removed (¼ in.)</td>
<td>18.3</td>
<td>0.33</td>
</tr>
<tr>
<td>All Slack Removed (½ in.)</td>
<td>18.5</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Observations:

Within the bounds of confidence provided by the tilt table test procedure, it would appear that the roll threshold of a tractor semitrailer combination can be improved slightly by removing the vertical slack present in the fifth wheel/kingpin coupling. Removal of the full ½ inch present in the test vehicle resulted in an improvement in the static roll threshold of slightly less than 4%. Recognising that the improvement in roll threshold attributed to increasing the trailer's track width by 6 inches was in the order of 7%, it would appear that there are potential benefits available in improving the tractor/trailer roll coupling.
5.2 Factors Affecting Tractor Semitrailer Static Roll Threshold

Based on the results of the tilt test program, the factors which affect the static roll threshold of the tractor semitrailer ranked in descending order of influence were as follows:

1. Centre of Gravity Height

The static roll threshold was most sensitive to changes in the centre of gravity height of the combination. In a loaded condition typical of "gross out - cube out" van type operations carrying medium density freight, the centre of gravity height would be expected to fall between 80 - 90 inches above the ground. Under these conditions, the static roll threshold of a conventionally equipped tractor-trailer would be in the 0.3 g lateral acceleration range. By way of comparison, the roll threshold of a conventional full sized passenger car would typically be in the 0.7 g lateral acceleration range.

2. Trailer Axle Width

The width of the trailer axles was found to be the second most influential variable examined in the tilt test program. It was determined that substitution of "102 inch" axles for "96 inch" axles improved the roll threshold by 7%, for trailer fitted with conventional dual, radial ply tires. Substituting wide base single tires for dual tires further increases the effective track width, and it was shown that, with single tires, moving from 96 inches to 102 inches improved the roll threshold by 11%.

3. Tractor Suspension Choice

The resistance to roll provided by the tractor
REFERENCES


APPENDIX 1

TEST VEHICLE DATA
TEST SERIES ONE:

INFLUENCE OF CENTRE OF GRAVITY HEIGHT
Description

TRACTOR TYPE: Inter F-9370
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 9,02M
TRAILER LENGTH: 14,78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 ZZA
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 ZZA
SUSPENSION TYPE ON TRACTOR: Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER: Reyco D16
AXLE SPREAD ON TRACTOR: 5,12M 1,55M
AXLE SPREAD ON TRAILER: 1,70M
TRACK WIDTH ON TRACTOR: 2,36M
TRACK WIDTH ON TRAILER: 2,25M
TIRE PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1,22M
AMBIENT TEMPERATURE: 10°C
Description

TRACTOR TYPE: 1975 Freightliner
TRAILER TYPE: Ram 13,71M Flat Bed
TRACTOR LENGTH: 6,64M
TRAILER LENGTH: 13,71M
TIRE TYPE ON TRACTOR: Michelin Radial HLR 24.5 XZA
TIRE TYPE ON TRAILER: Michelin Radial HLR 22.5 XZA
SUSPENSION TYPE ON TRACTOR: Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER: Kenco 21B
AXLE SPREAD ON TRACTOR: 3,47M 1,65M
AXLE SPREAD ON TRAILER: 1,37M
TRACK WIDTH ON TRACTOR: 2,43M
TRACK WIDTH ON TRAILER: 2,43M
TIRE PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1,32M
AMBIENT TEMPERATURE: 10°C
TEST SERIES TWO:

INFLUENCE OF SUSPENSION SELECTION
Description

TRACTOR TYPE: International 8370
TRAILER TYPE: 14.70m Flat Bed
TRACTOR LENGTH: 7.57m
TRAILER LENGTH: 14.70m
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 X2A
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 X2A
SUSPENSION TYPE ON TRACTOR: IH Air
SUSPENSION TYPE ON TRAILER: Chalmers 790
AXLE SPREAD ON TRACTOR: 4.80m 1.92m
AXLE SPREAD ON TRAILER: 1.18m
TRACK WIDTH ON TRACTOR: 2.40m
TRACK WIDTH ON TRAILER: 2.35m
TIRE PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1.21m
AMBIENT TEMPERATURE: 5°C
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Description

TRACTOR TYPE: International F-9270
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 7,72M
TRAILER LENGTH: 14,78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Chalmers 700
AXLE SPREAD ON TRACTOR: 4,96M 1,22M
AXLE SPREAD ON TRAILER: 1,69M
TRACK WIDTH ON TRACTOR: 2,17M
TRACK WIDTH ON TRAILER: 2,35M
TIRE PRESSURE ADJUSTED TO: 100 psi
HEIGHT OF THE FIFTH WHEEL: 1,22M
AMBIENT TEMPERATURE: 0°C
Description

TRACTOR TYPE: Case IH 9370
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 6,02M
TRAILER LENGTH: 14,78M
TIRES ON TRACTOR: Michelin Radial LR 22.5 x2A
TIRES ON TRAILER: Michelin Radial LR 22.5 x2A
SUSPENSION TYPE ON TRACTOR: Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER: Chalmers 700
AXLE SPREAD ON TRACTOR: 5,12M 1,55M
AXLE SPREAD ON TRAILER: 1,69M
TRACK WIDTH ON TRACTOR: 2,36M
TRACK WIDTH ON TRAILER: 2,35M
TIRES PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1,21M
AMBIENT TEMPERATURE: 5°C
Description

TRACTOR TYPE: International 7170
TRACTOR LENGTH: 7.22M
TRAILER TYPE: 14.78M Flat Bed
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 X2A
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 X2A
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Neway AR95-17
AXLE SPREAD ON TRACTOR: 4.76M 1.32M
AXLE SPREAD ON TRAILER: 1.87M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.35M
TIRE PRESSURE ADJUSTED TO: 100 psi
HEIGHT OF THE FIFTH WHEEL: 4.22M
AMBIENT TEMPERATURE: 10°C
Description

TRACTOR TYPE: Inter F-9370
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 7,79M
TRAILER LENGTH: 14,78M
TIRES TYPE ON TRACTOR: Michelin Radial 1IR 22.5 X2A
TIRES TYPE ON TRAILER: Michelin Radial 1IR 22.5 X2A
SUSPENSION TYPE ON TRACTOR: Neway ARD 244
SUSPENSION TYPE ON TRAILER: Neway AR95-17
AXLE SPREAD ON TRACTOR: 4,85M 1,55M
AXLE SPREAD ON TRAILER: 1,59M
TRACK WIDTH ON TRACTOR: 2,40M
TRACK WIDTH ON TRAILER: 2,75M
TIRES PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1,25M
AMBIENT TEMPERATURE: 19°C
Description

TRACTOR TYPE: Inter F-9270
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 9,02M
TRAILER LENGTH: 14,78M
TIRE TYPE ON TRACTOR: Michelin Radial HLR 22.5 X2A
TIRE TYPE ON TRAILER: Michelin Radial HLR 22.5 X2A
SUSPENSION TYPE ON TRACTOR: Hendrickson R1F 44V
SUSPENSION TYPE ON TRAILER: Neway AR75-17
AXLE SPREAD ON TRACTOR: 5,12M 1,55M
AXLE SPREAD ON TRAILER: 1,69M
TRACK WIDTH ON TRACTOR: 2,36M
TRACK WIDTH ON TRAILER: 2,35M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1,22M
AMBIENT TEMPERATURE: 10°C
Description

TRACTOR TYPE: Inter T-8370
TRAILER TYPE: 14.78M Flat Bed
TRACTOR LENGTH: 7.57M
TRAILER LENGTH: 14.78M
TIRES TYPE ON TRACTOR: Michelin Radial 11R 22.5 x2A
TIRES TYPE ON TRAILER: Michelin Radial 11R 22.5 x2A
SUSPENSION TYPE ON TRACTOR: 1H Air
SUSPENSION TYPE ON TRAILER: Neway AR95-17
AXLE SPREAD ON TRACTOR: 4.80M 1.32M
AXLE SPREAD ON TRAILER: 1.69M
TRACK WIDTH ON TRACTOR: 2.40M
TRACK WIDTH ON TRAILER: 2.35M
TIRES PRESSURE ADJUSTED TO: 100 psi
HEIGHT OF THE FIFTH WHEEL: 1.24M
AMBIENT TEMPERATURE: 16°C
**DESCRIPTION**

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Description

TRACTOR TYPE: Inter F-9370
TRAILER TYPE: 14.78M Flat Bed
TRACTOR LENGTH: 7.72M
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR: IH 4 Springs
SUSPENSION TYPE ON TRAILER: Keyco 21B
AXLE SPREAD ON TRACTOR: 4.96M 1.72M
AXLE SPREAD ON TRAILER: 1.70M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.35M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1.22M
AMBIENT TEMPERATURE: 10°C
### Description

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DESCRIPTION

TRACTOR TYPE: Inter H-93/0
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 8,02M
TRAILER LENGTH: 14,78M
TIRE TYPE ON TRACTOR: Michelin Radial LR 22,5 X2A
TIRE TYPE ON TRAILER: Michelin Radial LR 22,5 X2A
SUSPENSION TYPE ON TRACTOR: Hendrickson RFE 440
SUSPENSION TYPE ON TRAILER: Reyco 21B
AXLE SPREAD ON TRACTOR: 5,12M 1,55M
AXLE SPREAD ON TRAILER: 1,70M
TRACK WIDTH ON TRACTOR: 2,36M
TRACK WIDTH ON TRAILER: 2,35M
TIRE PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1,17M
AMBIENT TEMPERATURE: 2°C
TEST SERIES THREE:
INFLUENCE OF TRAILER AXLE WIDTH
DESCRIPTION

TRACTOR TYPE: Intern F-370
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 7,72M
TRAILER LENGTH: 14,78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER: Michelin Single 18.5R 22.5 XM+64
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 21E
AXLE SPREAD ON TRACTOR: 4,96M 1,72M
AXLE SPREAD ON TRAILER: 1,70M
TRACK WIDTH ON TRACTOR: 2,27M
TRACK WIDTH ON TRAILER: 2,33M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1,17M
AMBIENT TEMPERATURE: 10°C
DESCRIPTION

TRACTOR TYPE: Inter F-9376
TRACTOR LENGTH: 7.72M
TRAILER TYPE: 14.78M Flat Bed
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial LR 22.5 x2A
TIRE TYPE ON TRAILER: Michelin Single 16.5R 22.5 XM+54
SUSPENSION TYPE ON TRACTOR: IH 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 218
AXLE SPREAD ON TRACTOR: 4.96M 1.52M
AXLE SPREAD ON TRAILER: 1.70M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.51M
TIRE PRESSURE ADJUSTED TO: 160 Psi
HEIGHT OF THE FIFTH WHEEL: 1.17M
AMBIENT TEMPERATURE: 10°C
DESCRIPTION

TRACTOR TYPE: Inter F-9170
TRACTOR LENGTH: 7.72M
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XL A
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 XL A
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Rvco 21B
AXLE SPREAD ON TRACTOR: 4.56M 1.32M
AXLE SPREAD ON TRAILER: 1.70M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.35M
TIRE PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1.17M
AMBIENT TEMPERATURE: 10°C
Description

TRACTOR TYPE____________________: Inter F-9370
TRAILER TYPE___________________: 14,78M Flat Bed
TRACTOR LENGTH_______________: 7,72M
TRAILER LENGTH____________: 14,78M
TIRE TYPE ON TRACTOR________: Michelin Radial 11R 22.5 XZ A
TIRE TYPE ON TRAILER________: Michelin Radial 11R 22.5 XZ A
SUSPENSION TYPE ON TRACTOR____: IH 4 Springs
SUSPENSION TYPE ON TRAILER____: Reyco 21B
AXLE SPREAD ON TRACTOR_______: 4,96M 1,72M
AXLE SPREAD ON TRAILER_______: 1,72M
TRACK WIDTH ON TRACTOR_______: 2,37M
TRACK WIDTH ON TRAILER_______: 2,31M
TIRE PRESSURE ADJUSTED TO____: 100 Psi
HEIGHT OF THE FIFTH WHEEL_____: 1,17M
AMBIENT TEMPERATURE_________: 18°C
TEST SERIES FOUR:
INFLUENCE OF TIRE SELECTION
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TRACTOR TYPE: Inter F-9270
TRACTOR LENGTH: 7.72m
TRAILER TYPE: 14.78m Flat Bed
TRAILER LENGTH: 14.78m
TIRES TYPE ON TRACTOR: Michelin Radial 11R 22.5 XLA
TIRES TYPE ON TRAILER: Good Year Hi-Miler 10.00-20
SUSPENSION TYPE ON TRACTOR: H 4 Springs
SUSPENSION TYPE ON TRAILER: Revco 21B
AXLE SPREAD ON TRACTOR: 4.98m 1.32m
AXLE SPREAD ON TRAILER: 1.59m
TRACK WIDTH ON TRACTOR: 2.57m
TRACK WIDTH ON TRAILER: 2.54m
TIRES PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 4.21m
AMBIENT TEMPERATURE: 10°C
Description

TRACTOR TYPE: International F-9270
TRAILER TYPE: 14.78M Flat Bed
TRACTOR LENGTH: 7.72M
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZL
TIRE TYPE ON TRAILER: Michelin Single 16.5R 22.5 XM+54
SUSPENSION TYPE ON TRACTOR: IH 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 21B
AXLE SPREAD ON TRACTOR: 4.76M 1.32M
AXLE SPREAD ON TRAILER: 1.69M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.35M
TIRE PRESSURE ADJUSTED TO: 160 PSI
HEIGHT OF THE FIFTH WHEEL: 1.17M
AMBIENT TEMPERATURE: 10°C
**DESCRIPTION**

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TRACTOR TYPE: Inter F-2270
TRAILER TYPE: 14,78m Flat Bed
TRACTOR LENGTH: 7,72m
TRAILER LENGTH: 14,78m
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 X2A
TIRE TYPE ON TRAILER: Michelin Single 16.5R 20.5 XM-S4
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 21B
AXLE SPREAD ON TRACTOR: 4,96M 1,32M
AXLE SPREAD ON TRAILER: 1,69M
TRACK WIDTH ON TRACTOR: 2,37M
TRACK WIDTH ON TRAILER: 2,51M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1,17M
AMBIENT TEMPERATURE: 10°C
Description

TRACTOR TYPE: Inter P-9370
TRAILER TYPE: 14,79M Flat Bed
TRACTOR LENGTH: 7,72M
TRAILER LENGTH: 14,79M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 x2A
TIRE TYPE ON TRAILER: Michelin 275/80R 22.5 Pilot XA
SUSPENSION TYPE ON TRACTOR: JA 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 21F
AXLE SPREAD ON TRACTOR: 4,96M 1,22M
AXLE SPREAD ON TRAILER: 1,69M
TRACK WIDTH ON TRACTOR: 2,37M
TRACK WIDTH ON TRAILER: 2,51M
TIRE PRESSURE ADJUSTED TO: 100 PsI
HEIGHT OF THE FIFTH WHEEL: 1.17M
AMBIENT TEMPERATURE: 8°C
Description

TRACTOR TYPE: Case IH F-9270
TRAILER TYPE: 14.73M Flat Bed
TRACTOR LENGTH: 7.72M
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial TT 22.5 X2A
TIRE TYPE ON TRAILER: Good Year Super Hi-Miler 10.00-20
SUSPENSION TYPE ON TRACTOR: IH 4 Springs
SUSPENSION TYPE ON TRAILER: Kayco 21B
AXLE SPREAD ON TRACTOR: 4.86M 1.32M
AXLE SPREAD ON TRAILER: 1.69M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.51M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1.17M
AMBIENT TEMPERATURE: 8°C
TEST SERIES FIVE:

INFLUENCE OF FIFTH WHEEL VERTICAL SLACK
<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRACTOR TYPE:</td>
</tr>
<tr>
<td>TRAILER TYPE:</td>
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<tr>
<td>TRACTOR LENGTH:</td>
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<tr>
<td>TRAILER LENGTH:</td>
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<tr>
<td>TIRE TYPE ON TRACTOR:</td>
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<tr>
<td>TIRE TYPE ON TRAILER:</td>
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<td>SUSPENSION TYPE ON TRACTOR:</td>
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<td>SUSPENSION TYPE ON TRAILER:</td>
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<td>AXLE SPREAD ON TRACTOR:</td>
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<td>AXLE SPREAD ON TRAILER:</td>
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<tr>
<td>TRACK WIDTH ON TRACTOR:</td>
</tr>
<tr>
<td>TRACK WIDTH ON TRAILER:</td>
</tr>
<tr>
<td>TIRE PRESSURE ADJUSTED TO:</td>
</tr>
<tr>
<td>HEIGHT OF THE FIFTH WHEEL:</td>
</tr>
<tr>
<td>AMBIENT TEMPERATURE:</td>
</tr>
</tbody>
</table>
Description

TRACTOR TYPE: IH 4370
TRACTOR TYPE: 14,78 M Flat Bed
TRACTOR LENGTH: 7,72 M
TRACTOR LENGTH: 14,78 M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR: IH 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 216
AXLE SPREAD ON TRACTOR: 4,96M 1,32M
AXLE SPREAD ON TRAILER: 1,76M
TRACK WIDTH ON TRACTOR: 2,37M
TRACK WIDTH ON TRAILER: 2,35M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1,17 M
AMBIENT TEMPERATURE: 7°C
Description

TRACTOR TYPE: Inter F 9370
TRAILER TYPE: 14,78m Flat Bed
TRACTOR LENGTH: 7,72m
TRAILER LENGTH: 14,78m
TIRE TYPE ON TRACTOR: Michelin Radial LR 22.5 x2A
TIRE TYPE ON TRAILER: Michelin Radial LR 22.5 x2A
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 21B
AXLE SPREAD ON TRACTOR: 4,96m 1,32m
AXLE SPREAD ON TRAILER: 1,70m
TRACK WIDTH ON TRACTOR: 2,37m
TRACK WIDTH ON TRAILER: 2,35m
TIRE PRESSURE ADJUSTED TO: 100 psi
HEIGHT OF THE FIFTH WHEEL: 1,17m
AMBIENT TEMPERATURE: 8°C
APPENDIX 2

CALIBRATION OF INSTRUMENTATION
PAD LOAD CELLS
SPECIFICATIONS AND CALIBRATION
1. GENERAL DESCRIPTION:

1.1 Customer: Standard Product

1.2 Customer Part Number

1.3 OEM Outline Dwg: 6505P-10K/200K

2.0 PERFORMANCE SPECIFICATION:

2.1 Rated Capacity: 10K/200K

2.2 Rated Overload: 150

2.3 Rated Excitation: 15 VDC

2.4 Bridge Resistance

Output: 700 ± 7 Ohms

Input: 700 ± 7 Ohms

2.5 Full Scale Output: 3.0 MV

2.6 Performance: ± 1

2.7 Group: Less than .02% in 20 min.

2.8 Remainder:

Tolerance: N/A

Load: N/A

2.9 Inverters: ±0.03

2.10 Input Ohm Resistance: N/A

2.11 Conduction Temperature Range: 0-150

2.12 Thermal Zero Shift: ±0.015

2.13 Thermal Sensitivity Shift: ±0.0008

2.14 Identification: Standard

CERTIFIED
FEB 24 1983
838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K
CAPACITY 25K  S/N 100401
FULL SCALE OUTPUT 3.001 MV/V
DATE SHIPPED MAY 2 3 1985

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K
CAPACITY 25K  S/N 100399
FULL SCALE OUTPUT 3.002 MV/V
DATE SHIPPED MAY 2 3 1985

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K
CAPACITY 25K  S/N 100402
FULL SCALE OUTPUT 3.001 MV/V
DATE SHIPPED MAY 2 3 1985

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K
CAPACITY 25K  S/N 100400
FULL SCALE OUTPUT 2.997 MV/V
DATE SHIPPED MAY 2 3 1985
CALIBRATION CERTIFICATE
LOAD CELL

MODEL 60058-25K
CAPACITY 25K S/N 100405
FULL SCALE OUTPUT 3.007 MV/V
DATE SHIPPED MAY 2 3 1985

MODEL 60058-25K
CAPACITY 25K S/N 100403
FULL SCALE OUTPUT 2.099 MV/V
DATE SHIPPED MAY 2 3 1985

MODEL 100ER-25K
CAPACITY 25K S/N 100404
FULL SCALE OUTPUT 3.003 MV/V
DATE SHIPPED MAY 2 3 1985

MODEL 100ER-25K
CAPACITY 25K S/N 100402
FULL SCALE OUTPUT 3.002 MV/V
DATE SHIPPED MAY 2 3 1985
838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K  S/N 100413

FULL SCALE OUTPUT 2.004  MV/V

DATE SHIPPED MAY 23 1985

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K  S/N 100414

FULL SCALE OUTPUT 3.000  MV/V

DATE SHIPPED MAY 23 1985
TABLE TILT SENSOR:  Terra SA-111

INCLINOMETERS:  PENNYS AND GILES CETS/60
The Terra Flex® SA Series Servo Accelerometers offer the unparalleled combination of excellent stability and ruggedness. Designed for maximum user flexibility, standard features include field rangeability, choice of sensitive axis direction, and a 1g bias network which can be user connected.

A special alloy flexure system and stable differential electronic detector/amplifier are combined to provide high sensitivity, broad dynamic range, ruggedness, long term stability and extremely low thermal drift. Hysteresis is insignificant and resolution is effectively infinite. The flexure suspension, unlike pivot and jewel suspensions, is not subject to progressive deterioration in the presence of vibration and shock. Handling (peak) shock breakage, common with quartz suspensions, is also virtually eliminated.

The SA Series accelerometers operate from a wide range of input voltages and can be used for a variety of acceleration measurement applications including seismic monitoring, control systems, vibration monitoring, structural response, vehicle testing, stable platforms and tilt sensing.
SPECIFICATIONS FOR SA-102, SA-111

RANGE: 
±0.1 to 10g

FULL SCALE OUTPUT: 
±5 VDC (std) to ±10 VDC (max), ±0.5%

INPUT VOLTAGE: 
±9 to 18 VDC; +18 to 30 VDC (Telemetry version only)

INPUT CURRENT: 
±8 ma dual supply; 20 ma single supply (Telemetry version only)

OUTPUT IMPEDANCE: 
< 10 ohm

LINEARITY ERROR: 
< 0.05% full scale

HYSTERESIS: 
< 0.01% full scale

RESOLUTION: 
< 0.0005% full scale

TURN-ON REPEATABILITY: 
Better than 50 μg

CROSS AXIS SENSITIVITY: 
< 0.0005 g/g

FREQUENCY RESPONSE: 
0 to 50 Hz, ±2 dB (std), other frequency responses from 10 to 150 Hz available

NOISE: 
0-50 Hz < 5μg (peak-to-peak)
0-1000 Hz < 10μg (peak-to-peak)
0-1 MHz < 20μg (peak-to-peak)

CASE ALIGNMENT: 
< 0.5°

OPERATING TEMP. RANGE: 
-40°F to 180°F (std); -65°F to 300°F (special order)

SHOCK: 
500g, 5 ms; 3000 g, 0.1 ms

VIBRATION (SINE, PEAK): 
15g, 20-100 Hz; 20g, 100-2000 Hz

WEIGHT: 
7 oz (0.2 kg)

BIAS, HORIZONTAL: 
SA-102 0.010g SA-111 0.005g

BIAS, VERTICAL: 
SA-102 0.020g SA-111 0.010g

HORIZ. BIAS TEMP. COEF: 
50μg/°F max. 20μg/°F max.

SCALE FACTOR TEMP. COEF: 
100 ppm/°F max. 50 ppm/°F max.

NOTES
(1) UNITS ARE SUPPLIED WITH 0.1Ω INTERNAL RESISTOR. EXTERNAL RESISTORS ADDED TO INCREASE RANGE. STANDARD RANGES ARE: ±0.1, 0.25, 0.5, 1.0, 2.0, 5.0 and 10.0g ASYMMETRICAL RANGES AVAILABLE.

(2) FULL SCALE OUTPUT SHOULD NOT EXCEED 10 VDC OR 75% OF INPUT VOLTAGE, WHICHEVER IS SMALLER. TELEMETRY VERSIONS SUPPLIED WITH 0-3 VDC OUTPUT.

OUTLINE DIMENSIONS (inches)

CONNECTIONS

PIN DUAL SINGLE
1 + Power + Power
2 - Power Power Grd.
4† Output Output
5† 1g Bias 1g Bias
6* 1g Bias 1g Bias
7 Self Test Self Test
8 Self Test Self Test

* Jumper pins 5 & 6 for 1g bias, no connection for horizontal operation.
† Range resistor connected between pins 4 & 5.

PERFORMANCE OPTIONS
A. NON-STANDARD RANGE (Specify)
B. CASE ALIGNMENT: 1/4°
C. INITIAL BIAS: 0.002g (horizontal) 0.005g (vertical)
D. BIAS T.C. 10 μg/°F (SA-111 only, not applicable to vertical bias)
E. SCALE FACTOR TOLERANCE: ±0.1%
F. TELEMETRY OUTPUT: 0-5 VDC

ORDERING INFORMATION: Specify model number, range, sensitive direction, and performance options desired. For example, SA-102-1-B-F is a Model SA-102, ±1g, with case alignment of 1/4° and telemetry output. Full scale output is ±5 VDC unless otherwise specified on this order (except for telemetry versions which are 0-5 VDC).

WANT MORE INFORMATION? CONTACT TERRA TECHNOLOGY CORP. OUR FACTORY PERSONNEL CAN PROVIDE YOU WITH ADDITIONAL INFORMATION, WHETHER IT'S FOR A SINGLE INSTRUMENT OR A COMPLETE SYSTEM PROPOSAL.

TERRA TECHNOLOGY CORP.
3860 148TH AVENUE N.E., REDMOND, WASHINGTON 98052 • Phone (206) 883-7300 • Cable TERRATECH • Telex 32-0357

PRINTED IN USA
Tilt Sensors

- Potentiometric or variable transformer outputs
- Single or dual axis sensing
- Tilt sensing from 4° to 356°
- Robust instruments plus fully sealed option
- Industrial and military environmental specifications
- Sensor accuracies from ±4 minutes of arc
- Low cost units available

The range of tilt sensors available from Penny & Giles Potentiometers Ltd comprises high sensitivity infinite resolution variable transformer units, transducers with potentiometric outputs, a series of low cost units specifically designed to meet those applications that require sensors of comparatively low accuracies, and tilt sensors with high accuracies designed and packaged for military requirements. Both the high sensitivity/infinite resolution models and the potentiometric units are available packaged for normal industrial use or completely sealed for use in the most adverse environments. Additionally they can be specified in brass for underground applications and for underwater down to 300 metres.

The tilt sensors designed to meet military or similar demanding requirements are temperature compensated to achieve the very high accuracies required. They are available in four ranges from 4° to 200° in both X and X+Y axes.

Full details of each tilt sensor in the range are shown on the following pages.
- High sensitivity/infinite resolution models — page 2
- Low cost models — page 3
- Potentiometric output sensors — page 4
- High accuracy/temperature compensated sensors for military applications — page 6
Tilt Sensors
Variable Transformer Models
LOW COST

Performance specification

<table>
<thead>
<tr>
<th>Model number</th>
<th>CFETS/200</th>
<th>CFETS/100</th>
<th>CFETS/60</th>
<th>CFETS/30</th>
<th>CFETS/20</th>
<th>CFETS/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilt measurement range</td>
<td>200 degrees</td>
<td>100 degrees</td>
<td>60 degrees</td>
<td>30 degrees</td>
<td>20 degrees</td>
<td>4 degrees</td>
</tr>
<tr>
<td>Output sensitivity per degree into 10kΩ load ±0.2%</td>
<td>45mV</td>
<td>90mV</td>
<td>140mV</td>
<td>240mV</td>
<td>340mV</td>
<td>470mV</td>
</tr>
<tr>
<td>Residual voltage – maximum at 0° arc</td>
<td>50mV</td>
<td>500mV</td>
<td>1.0V</td>
<td>1.0V</td>
<td>1.0V</td>
<td>1.0V</td>
</tr>
<tr>
<td>Linearity – deviation from best straight line</td>
<td>±0.5%</td>
<td>±0.5%</td>
<td>±0.5%</td>
<td>±0.5%</td>
<td>±0.5%</td>
<td>±0.5%</td>
</tr>
<tr>
<td>Mechanical angle</td>
<td>360°</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input voltage</td>
<td>10 volts a.c. from a source impedance of less than 1 ohm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output</td>
<td>10V d.c. into 10kΩ load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resolution</td>
<td>infinite</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hysteresis – maximum</td>
<td>30 minutes of arc</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature range – operational</td>
<td>-20°C to +60°C (non derangement -40°C to 100°C)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean temperature coefficient</td>
<td>+10°C to +40°C ±0.80mV per °C</td>
<td>-20°C to +60°C ±2.00mV per °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output ripple (1.2kHz)</td>
<td>0.05% FS +0.4% output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input current – nominal</td>
<td>50mA at 10.000V a.c.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight – maximum</td>
<td>100 gm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The specification data given above is true at 10000V a.c. input with a 10kΩ load impedance on output.

Dimensions

[Diagram showing dimensions in millimetres (inches)]

Output characteristic

[Diagram showing output characteristic]

Electrical connections – all models

high sensitivity model – 3910
NORMAL DUTY SENSOR

low cost model – CFETS
NORMAL DUTY SENSOR

COMPLETELY SEALED SENSOR (IN) (OUT)
DATA ACQUISITION SYSTEM

COMPUTER: HP 9816
DATA LOGGER: HP 3497A
INPUT VOLTAGE CARD: HP 44427 A/B
DATA ACQUISITION SYSTEM
Model 236

The Model 236CS includes the Model 236C base color system, with an additional 512 Kbyte RAM (640 Kbyte total), BASIC 3.0 and Pascal 3.0. It has an socket for backplane slots.

The Model 236U is based on the Model 236A, includes 512 Kbyte additional RAM (640 Kbyte total), BASIC 3.0 and Pascal 3.0. Six backplane slots are standard.

The Model 236T is based on the Model 236U, includes four backplane slots, 1.02 Mbyte RAM, and single-or multi-user HP-UX with C, FORTRAN 77, and HP Pascal/68000 Assembler, and Graphics/9000 DGL.

Model 236CT is based on the Model 236CU base color system, includes 1.02 Mbyte RAM, single-or multi-user HP-UX with C, FORTRAN 77, HP Pascal/68000 Assembler, and Graphics/9000 DGL.

Model 237

The Model 237 is a high-performance graphics workstation featuring high-resolution display and a 12.5 MHz processor. It provides the power and speed required by engineers and scientists involved in laboratory analysis, printed circuits, and integrated circuit board design, mathematical modeling, statistics, and 3-D mechanical drafting.

The Model 237H features the 12.5 MHz processor with memory management hardware and cache memory, a 431 mm (17-inch) monochrome display with 1024 x 768 resolution and bit-mapping capabilities, built-in HP-IB floating-point main hardware, the HP-IL keyboard, mouse, and 312 Kbyte RAM.

HP 9000 Series 200

9816A Model 216S Computer w/BASIC
9817A Model 217A Computer
9817H Model 217H Computer w/512K RAM, keyboard and terminal
9817L Model 217L Computer w/1 MB RAM, keyboard, terminal & single-user HP-UX
9920A Model 220A Modular Computer
9930U Model 220U Modular Computer w/12.5 MHz Processor
9930S Model 220S Modular Computer w/keyboard, BASIC, Pascal, 640 K byte RAM
9920T Model 220T Modular Computer w/12.5 MHz Processor, single-user HP-UX, keyboard
9920A Model 222A Computer
9923S Model 222S Computer w/640 K byte RAM, BASIC, Pascal, and SRM
9836A Model 236A Computer

Languages and Operating Systems

HP 98601A ROM-based BASIC 2.0 Language System. Includes one system ROM board, BASIC 2.0 Language Manual Kit, and BASIC 2.0 Utilities Pack
HP 98602A ROM-based BASIC 2.0 plus extensions 2.1. Includes one ROM board, BASIC 2.0 with Extensions Manual Kit and BASIC 2.0 Utilities Pack
HP 98603A ROM-based BASIC 4.0 Language System. Includes one ROM-based system board, HPL 4.0 Language Manual Kit and BASIC 4.0 Utilities Pack
HP 98604A ROM-based HPL 2.0 Language System. Includes one system ROM board, HPL 2.0 Language Manual Kit, and HPL 2.0 Utilities. (Not available for Models 220 or 236C)
HP 98613A ROM-based BASIC 3.0 Language System. Includes system flexible disk and Language Extensions disk, BASIC 3.0 Language Manual Kit, and BASIC 2.0 Utilities Pack
HP 98613B ROM-based BASIC 4.0 Language System. Includes system flexible disk and Language Extensions Disk, BASIC 4.0 Language Manual Kit and BASIC 4.0 Utilities Pack
HP 98614A ROM-based HPL 2.0 Language System. Includes System Flexible disk, HPL 2.0 Language Manual Kit, and HPL 2.0 Utilities Pack. (Not available for Models 220 or 236C)
HP 98615B ROM-based Pascal 3.0 Language System. Includes system flexible disk and Pascal 3.0 Language Manual Kit
HP 98670A Single-user HP-UX Operating System
HP 98880A Multi-user HP-UX Operating System.
DATA ACQUISITION, CONTROL & TEST
Data Acquisition/Control Unit
HP Model 3497A

- Relay multiplexing
- DVM
- FET multiplexer
- Real time clock
- Bridge completion
- Digital inputs/outputs
- Counter
- Programmable D/As
- Optional RS-232C interface

HP 3497A

Description
The HP 3497A Data Acquisition/Control Unit combines the capabilities of several instruments and is a basic building block of an automatic data acquisition and control system. The HP 3497A will be used in an HP-IB automated system and can be viewed as a precision measurement and control computer peripheral.

The HP 3497A has been designed to be a very versatile and powerful instrument. It has a basic HP 3497A consists of a mainframe that includes a front panel, keyboard, and display, a non-volatile real time clock, and an HP-IB interface. Available as an option is a 5½-digit integrating digital voltmeter and current source that occupies a dedicated slot in the HP 3497A chassis. Capability is added to the HP 3497A by using any combination of plug-in assemblies. Available plug-in assemblies are:

- Relay Multiplexers
- Digital Input/Output
- Counter
- Strain gage/bridge completion
- Voltage
- Active voltage and current D/As
- Breadboard Assembly

Up to 5 assemblies can be added to a HP 3497A and the HP 3498A. An assembly can hold up to 10 more plug-in assemblies.

High Performance
The HP 3497A DVM can resolve 1 microvolt signals and is ideal for the precise measurement of the outputs of thermocouples, strain gage, and other transducers. Included in the DVM is a programmable current source that allows four-terminal resistance measurements. The multiplexer assembles switch 3 wires (Hi, Lo, and Guard) and add less than 2 microvolts of thermal offset to the measured signal.

Flexible Hardware Configuration
The HP 3497A card cage can hold 5 of any combination of the plug-in assemblies. This allows the multiplexing of up to 100 3-wire inputs to the DVM in a single HP 3497A or a single HP 3497A might contain 60 multiplexer channels, 16 digital inputs, 16 analog outputs, and a DVM. By using the HP 3498A Extender, up to 1000 analog channels and 1300 digital channels can be controlled, all at a single bus address.

Ease of Use
The HP 3497A keyboard and display make the HP 3497A very easy to use and makes debugging of a HP 3497A based system easy. The calibration adjustments for the HP 3497A DVM are located behind a hinged front panel, this allows complete calibration of the DVM without removing it from the test rack. Connections to all of the HP 3497A assemblies are made using screw terminals, thereby eliminating the need for soldering.

Automatic Data Acquisition and Control Systems
The HP 3497A is an integral part of the HP 3054A/C Automatic Data Acquisition and Control Systems. The HP 3054A consists of a HP 3456A Digital Voltmeter for high accuracy measurements, a HP 3437A Systems Voltmeter for high speed measurements and an HP 3497A for multiplexing, digital I/O and control. The HP 3054A includes software compatible with the HP 85 and Series 200 computers. The HP 3054C is similar to the HP 3054A but it does not include the HP 3437A and the software is compatible with the HP 1000 series of computers. The HP 3457A is also a part of the HP 3054 DL data logger.

Real Time Clock
The HP 3497A mainframe includes a quartz-referenced, non-volatile real-time clock. In addition to providing timekeeping, the clock can measure elapsed time, interrupt at a presettable time, and output a programmable pulse train.

Clock Format
Month:Day:Hours:Minutes:Seconds (U.S. Format)
Day:Month:Hours:Minutes:Seconds (European Format)

<table>
<thead>
<tr>
<th>Modes</th>
<th>Max. Time</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Time Mode</td>
<td>1 year</td>
<td>1 second</td>
<td>±0.05% of time ± 1 s</td>
</tr>
<tr>
<td>Elapsed Time Mode</td>
<td>10^9 seconds</td>
<td>1 second</td>
<td>±0.05% of time ± 1 s</td>
</tr>
<tr>
<td>Time Alarm Mode</td>
<td>24 hours</td>
<td>1 second</td>
<td>±0.05% of time ± 1 s</td>
</tr>
<tr>
<td>Timer Interval Mode</td>
<td>24 hours</td>
<td>1 second</td>
<td>±0.05% of time ± 1 s</td>
</tr>
<tr>
<td>Timer Output Mode</td>
<td>1 second</td>
<td>100 μs</td>
<td>±0.01% of time</td>
</tr>
</tbody>
</table>
SYSTEM ACCURACY SPECIFICATIONS:

These system specifications combine individual accuracy specifications to result in a total measurement accuracy specification. For example, the resistance specifications combine the DVM, current source and acquisition assembly error terms.

Voltage Measured Through Acquisition Assembly

3497A Configuration:
DVM: 5½ digit, auto zero on
Relays Switches: Tree Switched

Accuracy: ± (% of reading + number of counts)

90 Days 23°C ± 5°C

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Digits Displayed</th>
<th>Range</th>
<th>5½ digits</th>
<th>4½ digits</th>
<th>3½ digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 V</td>
<td>0.007 + 5</td>
<td>0.01</td>
<td>2</td>
<td>0.1 + 1</td>
<td></td>
</tr>
<tr>
<td>1.0 V</td>
<td>0.006 + 7</td>
<td>0.01</td>
<td>1</td>
<td>0.1 + 1</td>
<td></td>
</tr>
<tr>
<td>10.0 V</td>
<td>0.006 + 1</td>
<td>0.01</td>
<td>1</td>
<td>0.1 + 1</td>
<td></td>
</tr>
<tr>
<td>100.0 V</td>
<td>0.006 + 1</td>
<td>0.01</td>
<td>1</td>
<td>0.1 + 1</td>
<td></td>
</tr>
</tbody>
</table>

Resistance Measured Through Acquisition Assembly

3497A Configuration:
DVM: 5½ digit, auto zero on
Current Source: As indicated
Relay Switches: Configured for a 4-terminal resistance measurement

Characteristics

<table>
<thead>
<tr>
<th>Effective Resistance</th>
<th>Effective Resistance</th>
<th>Current Source</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range</td>
<td>Resolution</td>
<td>Range</td>
<td>Range</td>
</tr>
<tr>
<td>100 Ω</td>
<td>1 mΩ</td>
<td>100 μA</td>
<td>100000</td>
</tr>
<tr>
<td>1 kΩ</td>
<td>10 mΩ</td>
<td>100 μA</td>
<td>100000</td>
</tr>
<tr>
<td>10 kΩ</td>
<td>100 mΩ</td>
<td>100 μA</td>
<td>100000</td>
</tr>
<tr>
<td>100 kΩ</td>
<td>1 kΩ</td>
<td>10 μA</td>
<td>100000</td>
</tr>
</tbody>
</table>

Accuracy: ± (% of reading + number of counts)

90 Days 23°C ± 5°C

<table>
<thead>
<tr>
<th>Range (Relays Opt. 010)</th>
<th>5½ digits</th>
<th>4½ digits</th>
<th>3½ digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Ω</td>
<td>0.092 + 5</td>
<td>0.055 + 2</td>
<td>0.125 + 1</td>
</tr>
<tr>
<td>1 kΩ</td>
<td>0.0092 + 5</td>
<td>0.0055 + 2</td>
<td>0.0125 + 1</td>
</tr>
<tr>
<td>10 kΩ</td>
<td>0.00092 + 5</td>
<td>0.00055 + 2</td>
<td>0.00125 + 1</td>
</tr>
<tr>
<td>100 kΩ</td>
<td>0.000092 + 5</td>
<td>0.000055 + 2</td>
<td>0.000125 + 1</td>
</tr>
</tbody>
</table>

System Noise Rejection

Normal Mode Rejection (NMR): (50 or 60 Hz. ± 0.05%)

<table>
<thead>
<tr>
<th>DVM Digits</th>
<th>Rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>5½</td>
<td>60 dB</td>
</tr>
<tr>
<td>4½</td>
<td>0 dB</td>
</tr>
<tr>
<td>3½</td>
<td>0 dB</td>
</tr>
</tbody>
</table>

NMR is a function of the 3497A DVM configuration only and is not affected by the number of channels in the system.

Effective Common Mode Rejection (ECMR): The ECMR of a 3497A based system is a combination of the ECMR of the 3497A DVM and the effects of adding multiplexer assemblies and 3498A extenders.

ECMR: (1 kΩ imbalance in low lead, using tree switching, ac at 50 or 60 Hz, 25°C, < 85% R.H.)

VOLTMETER CONFIGURATION

Number of Acquisition Channels

<table>
<thead>
<tr>
<th>Option</th>
<th>5½ Digits</th>
<th>4½ Digits</th>
<th>3½ Digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>120 dB</td>
<td>120 dB</td>
<td>120 dB</td>
</tr>
<tr>
<td>20</td>
<td>104 dB</td>
<td>104 dB</td>
<td>104 dB</td>
</tr>
<tr>
<td>&lt;100</td>
<td>92 dB</td>
<td>92 dB</td>
<td>92 dB</td>
</tr>
<tr>
<td>&lt;400</td>
<td>85 dB</td>
<td>85 dB</td>
<td>85 dB</td>
</tr>
<tr>
<td>&lt;1000</td>
<td>70 dB</td>
<td>70 dB</td>
<td>70 dB</td>
</tr>
</tbody>
</table>

Measurement Speeds

For the 3497A DVM and the relay multiplexer.

Speeds are given for measurements on random channels (using software channel selection) and sequential channels (using external hardware increment). Speeds include I/O times to the indicated computers.

VOLTMETER DIGITS DISPLAYED

<table>
<thead>
<tr>
<th>Voltmeter Digits Displayed</th>
<th>5½A 3½A 2½A 1½A 1000 10000</th>
<th>Measurement (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential Channels</td>
<td>5nA 10nA 20nA 40nA 50nA 100nA</td>
<td>100nA 1000nA 10000nA</td>
</tr>
<tr>
<td>Random Channels</td>
<td>4nA 8nA 16nA 32nA 64nA 128nA</td>
<td>128nA 256nA 512nA 1024nA</td>
</tr>
</tbody>
</table>

23
Option 001—5½ Digit DVM and Current Source

The HP 3497A DVM assembly is a systems quality, 5½ digit, 1 microvolt sensitive dc voltmeter. The DVM is fully guarded and uses an integrating A/D conversion technique; this yields excellent common and normal mode noise rejection. Included on the DVM assembly is a three level programmable current source. The current source, when used simultaneously with the DVM, can be used to make high accuracy four terminal resistance measurements with 1 millivolt resolution. Maximum speed is 300 readings per second in 5½ digit mode.

Voltmeter Specifications

<table>
<thead>
<tr>
<th>Range</th>
<th>Max Display</th>
<th>5% Digit Resolution</th>
<th>Accuracy 90 Days, 23°C ±5°C</th>
<th>5% Digits</th>
<th>Input Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 V</td>
<td>±119999</td>
<td>1 µV</td>
<td>±0.007% RDG + 3 counts</td>
<td>10¹Ω</td>
<td></td>
</tr>
<tr>
<td>1.0 V</td>
<td>±119999</td>
<td>10 µV</td>
<td>±0.006% RDG + 1 count</td>
<td>10¹Ω</td>
<td></td>
</tr>
<tr>
<td>100 V</td>
<td>±119999</td>
<td>100 µV</td>
<td>±0.006% RDG + 1 count</td>
<td>10¹Ω</td>
<td></td>
</tr>
<tr>
<td>1000 V</td>
<td>±119999</td>
<td>1 mV</td>
<td>±0.006% RDG + 1 count</td>
<td>10¹Ω</td>
<td></td>
</tr>
</tbody>
</table>

Maximum Input Voltage

High to low: 120 V peak
Low to guard: 170 V peak
Guard to chassis: 170 V peak

Current Source

Accuracy: 90 days

<table>
<thead>
<tr>
<th>Range</th>
<th>23°C ±5°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 µA</td>
<td>2.5 nA</td>
</tr>
<tr>
<td>100 µA</td>
<td>25 nA</td>
</tr>
<tr>
<td>1 nA</td>
<td>250 nA</td>
</tr>
</tbody>
</table>

Compliance: >±15 volts
Isolation voltage: 170 volts peak

General Information

Maximum Reading Rate: (readings/second)

<table>
<thead>
<tr>
<th>Auto Zero</th>
<th>60 Hz Operation Digits Displayed</th>
<th>50 Hz Operation Digits Displayed</th>
</tr>
</thead>
<tbody>
<tr>
<td>ON</td>
<td>25 100 150 20 85 125</td>
<td>50 200 300 40 166 250</td>
</tr>
<tr>
<td>OFF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Delay: 0 to 99.9999 seconds in 100 µs steps
Buffer size: packed format 100 readings; ASCII format: 60 readings
Number of readings per trigger: 1 to 999

Measurement Speeds

For the HP 3497A DVM and the relay multiplexer, speeds are given for measurements on random channels (using software channel selection) and sequential channels (using external hardware increment). Speeds include 1/0 times to the indicated computers

80 Hz Operation (50 Hz operation)

<table>
<thead>
<tr>
<th>Number of Digits Selected</th>
<th>80</th>
<th>Computer</th>
<th>8524*</th>
<th>1000L</th>
<th>1000ES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequential Channels using external increment</td>
<td>5½ digits</td>
<td>39 (39)</td>
<td>39 (25)</td>
<td>30 (25)</td>
<td></td>
</tr>
<tr>
<td>4½ digits</td>
<td>39 (39)</td>
<td>39 (25)</td>
<td>30 (25)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3½ digits</td>
<td>127 (109)</td>
<td>123</td>
<td>127 (109)</td>
<td>107 (99)</td>
<td></td>
</tr>
</tbody>
</table>

Random Channels using software

| 5½ digits | 13 (13) | 27 | 21 (26) | 22 (16) |
| 4½ digits | 14 (13) | 51 | 31 (28) | 35 (30) |
| 3½ digits | 14 (13) | 55 | 22 (29) | 35 (28) |

*852426 specifies for BASIC operating system

Option 010—20 Channel Relay Multiplexer

This assembly uses relay channels to input signals to the DVM or other instruments. Each assembly switch has 20 channels, each channel consists of HI, LO, and Guard lines. Two channels may be closed per assembly and relays may be closed in a random sequence or incremented between programmable limits. The low thermal offset of the relays make it suitable for measuring the output of strain gage and other transducers. Each channel can be configured with a filter or current shunt for additional flexibility.

Input Characteristics

Maximum input voltage: <170 V peak between any two input terminals
Maximum current: 50 mA per channel non-inductive
Maximum power: 1 VA per channel
Thermal offset: direct switched, <1 µV differential; tree switched, <2 µV differential
Closed Channel Resistance

In series: 100 Ω ±10% in High, Lo and Guard
Relays contacts only: <1 Ω per contact
Open channel isolation: >10¹⁰ (2H to Lo, 40°C, <60% R.H.)
Maximum switch rate: 475/s (using hardware increments)
Rated switch life at 1 VA: 10⁸ operations
All Relays are Break-Before-Make

Option 020—Relay Multiplexer with Thermocouple Compensation

The option 020 assembly uses the same relay multiplexer as option 010 but incorporates a special thermocouple connector block to allow thermocouple compensation. Two types of compensation (selectable by the user) are available. A temperature-dependent voltage is generated for software compensation; the voltage is then used in a computer program to compensate the thermocouple voltage. Hardware compensation involves inserting a voltage in the measurement circuit that automatically compensates the thermocouple voltage.

Reference Junction Compensation Comparison

<table>
<thead>
<tr>
<th>Software</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare Thermocouples</td>
<td>Any mature</td>
</tr>
<tr>
<td>Measurement channels available per assembly</td>
<td>19</td>
</tr>
<tr>
<td>Reference junction compensation accuracy (23°C ± 5°C)</td>
<td>0.1°C</td>
</tr>
</tbody>
</table>
### Table 1-1. Specifications

#### Accuracy:
These specifications include all system related errors: bridge resistor tolerance and drift, thermal offsets of bridge, scanner and voltmeter, voltmeter accuracy, injected currents, self-heating of bridge resistors and system noise. The only exceptions are lead wire mismatch and accuracy of the gage itself. Specifications are valid for either the 3497A or the 3456A voltmeter with integration time set to one power line cycle.

All specifications are ± and are valid for the following temperature and relative humidity extremes:

| Temperature and Humidity | 25°C/65% R.H. | 40°C/60% R.H. |

#### Accuracy at Vin = 5 Volts

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>24 hr ±1°C</th>
<th>24 hr ±3°C</th>
<th>&gt;90 Days</th>
<th>Temperature Coefficients (0 16.28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>1 µV</td>
<td>1 µV</td>
<td>0.04 µV/Mo</td>
<td>0.025 µV/°C</td>
</tr>
<tr>
<td>1/2</td>
<td>4 µV</td>
<td>5 µV</td>
<td>0.4 µV/Mo</td>
<td>0.3 µV/°C</td>
</tr>
<tr>
<td>1/4</td>
<td>7 µV</td>
<td>25 µV</td>
<td>1.8 µV/Mo</td>
<td>1.8 µV/°C</td>
</tr>
</tbody>
</table>

#### Accuracy at Vin = 100 mV

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>24 hr ±1°C</th>
<th>24 hr ±3°C</th>
<th>&gt;90 Days</th>
<th>Temperature Coefficients (0 16.28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>20 µV</td>
<td>35 µV</td>
<td>0.04 µV/Mo</td>
<td>0.8 µV/°C</td>
</tr>
<tr>
<td>1/2</td>
<td>40 µV</td>
<td>75 µV</td>
<td>0.9 µV/Mo</td>
<td>1.7 µV/°C</td>
</tr>
<tr>
<td>1/4</td>
<td>80 µV</td>
<td>150 µV</td>
<td>6.8 µV/Mo</td>
<td>3.6 µV/°C</td>
</tr>
</tbody>
</table>

#### Accuracy at Vin = 1 Volt

<table>
<thead>
<tr>
<th>Bridge Type</th>
<th>24 hr ±1°C</th>
<th>24 hr ±3°C</th>
<th>&gt;90 Days</th>
<th>Temperature Coefficients (0 16.28°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>3123 µV</td>
<td>x 23 µV</td>
<td>x 30 µV</td>
<td>±102 µV</td>
</tr>
<tr>
<td>1/2</td>
<td>-1023 µV</td>
<td>x 23 µV</td>
<td>x 25 µV</td>
<td>±101 µV</td>
</tr>
<tr>
<td>1/4</td>
<td>-294 µV</td>
<td>x 57 µV</td>
<td>x 40 µV</td>
<td>±116 µV</td>
</tr>
</tbody>
</table>

#### Notes:
1. Internal and external shunt calibration value will vary from channel to channel due to gage tolerances (± 0.5%), path resistances in the low thermal relay board (0.05 to 1.1 ohms), and leadwire resistance.
2. For 1/2 bridge (2 gages with equal and opposite strain) and full bridge (4 gages with equal strain arranged for maximum output) specifications, divide every number by 2 and 4 respectively.
3. Hardware shunt resistors provided on the Model 44427A/B are:
   - External gage = 59.41 K ohms, ±0.27%
   - Internal gage = 39.81 K ohms, ±0.27%
4. The leadwire adder assumes equal resistances in the 3 (or 4) wire cable, and the specification uses the resistance of only one leadwire.
5. The internal shunt has leadwires in the full bridge configuration. The leadwire adder maximum value is ± 0.7 µV/Mo (for 120 and 350 ohm gages, full bridge). The full bridge internal shunt value will be larger than predicted by 2.6 µV ± 2.4 µV due to the relay card resistance (note that this resistance acts like an additional leadwire resistance of between 0.05 ohms and 1 ohm).

#### Effective Common Mode Rejection (ECMR):
3497A with internal voltmeter, set for 1 power line cycle, strain gage cards, all channels driven by a single common mode source.

<table>
<thead>
<tr>
<th>Number of Channels</th>
<th>ECMR (db)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 50</td>
<td>150</td>
</tr>
<tr>
<td>≤ 150</td>
<td>144</td>
</tr>
<tr>
<td>≤ 250</td>
<td>140</td>
</tr>
<tr>
<td>≤ 350</td>
<td>138</td>
</tr>
<tr>
<td>≤ 450</td>
<td>136</td>
</tr>
<tr>
<td>≤ 500</td>
<td>134</td>
</tr>
</tbody>
</table>

#### Additional Strain Error Due At 40°C, 95% R.H.:
Strain error due to leakage current flowing into LO common is given by:

\[ e = \frac{1 \text{ leak} + 1428}{(N + Gf) - \text{Vin} \text{ (in)}} \]

Where
- \( N \) = 1 for 1/4 Bridge
- 2 for 1/2 Bridge
- 4 for Full Bridge
- \( Gf \) = Gage factor
- 1 leak = 100 nA card + 100 nA/Mainframe (or Extender)

### Strain Gage

1-3/1-4
APPENDIX 3

TEST DATA SUMMARIES
### Task One: Baselines Vehicles

**DESCRIPTION**

<table>
<thead>
<tr>
<th>Description</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor Type</td>
<td>1975 Freightliner</td>
</tr>
<tr>
<td>Tractor Length</td>
<td>14.78m Flat Bed</td>
</tr>
<tr>
<td>Tractor Length</td>
<td>6.84m</td>
</tr>
<tr>
<td>Tractor Length</td>
<td>14.78m</td>
</tr>
<tr>
<td>Tire Type on Tractor</td>
<td>Michelin Radial 11R 24.5 XZA</td>
</tr>
<tr>
<td>Tire Type on Trailer</td>
<td>Michelin Radial 11R 22.5 XZA</td>
</tr>
<tr>
<td>Suspension Type on Tractor</td>
<td>Hendrickson RFE 440</td>
</tr>
<tr>
<td>Suspension Type on Trailer</td>
<td>Fruhauf 4 Springs</td>
</tr>
<tr>
<td>Suspension Type on Lifts Axles</td>
<td>2 Neway AR95 Lift Axle</td>
</tr>
<tr>
<td>Axle Spread on Tractor</td>
<td>3.47m 1.85m</td>
</tr>
<tr>
<td>Axle Spread on Trailer</td>
<td>2.74m Each</td>
</tr>
<tr>
<td>Track Width on Tractor</td>
<td>2.45m</td>
</tr>
<tr>
<td>Track Width on Trailer</td>
<td>2.42m</td>
</tr>
<tr>
<td>Tire Pressure Adjusted To</td>
<td>100 psi</td>
</tr>
<tr>
<td>Height of the Fifth Wheel</td>
<td>1.30m</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>12°C</td>
</tr>
</tbody>
</table>
Special Case: 5 Axles Tractor-Trailer

- Henderson Tractor, Walking Beam Trailer, 86 in.
- Trailer, Tandem Axles, Load (High Side)
- Trailer, Tandem Axles, Load (Low Side)

Load (ft-lb) vs. Tare 

Tire Angle (R.)
Special Case: 6 Axles Tractor-Trailer

- tractor, working beam trailer 92 in.
- tractor tandem axle load (high side)
- trailer tandem axle load (low side)
- trailer air bag axle load (high side)

Load (lb)

Table angle (R.)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Special Case: 7 Axles Tractor-Trailer

- Hendrickson Tractor, Walking Beam Trailer 96 in
- Tractor Tandem Axles Load (High Side)
- Tractor Tandem Axles Load (Low Side)
- Trailer Air Bag Axles Load (High Side)
**Task One: Baseline Vehicles**

**DESCRIPTION**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TRACTOR TYPE</strong></td>
<td>1975 Freightliner</td>
</tr>
<tr>
<td><strong>TRAILER TYPE</strong></td>
<td>A-Train Flat Bed</td>
</tr>
<tr>
<td><strong>TRACTOR LENGTH</strong></td>
<td>8.84m</td>
</tr>
<tr>
<td><strong>TRAILER LENGTH</strong></td>
<td>2x7.72m</td>
</tr>
<tr>
<td><strong>TIRE TYPE ON TRACTOR</strong></td>
<td>Michelin Radial 11R 24.5 x2A</td>
</tr>
<tr>
<td><strong>TIRE TYPE ON TRAILERS</strong></td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td><strong>SUSPENSION TYPE ON TRACTOR</strong></td>
<td>Hendrickson RKE 440</td>
</tr>
<tr>
<td><strong>SUSPENSION TYPE ON TRAILERS</strong></td>
<td>4 Springs Reyco 21B</td>
</tr>
<tr>
<td><strong>SUSPENSION TYPE ON DOLLY</strong></td>
<td>2 Springs Reyco 21B</td>
</tr>
<tr>
<td><strong>AXLE SPREAD ON TRACTOR</strong></td>
<td>3.47m 1.25m</td>
</tr>
<tr>
<td><strong>AXLE SPREAD ON TRAILER</strong></td>
<td>1.24m 2.90m 4.96m 1.24m</td>
</tr>
<tr>
<td><strong>TRACK WIDTH ON TRACTOR</strong></td>
<td>2.43m</td>
</tr>
<tr>
<td><strong>TRACK WIDTH ON TRAILER</strong></td>
<td>2.43m</td>
</tr>
<tr>
<td><strong>TIRE PRESSURE ADJUSTED TO</strong></td>
<td>100 Psig</td>
</tr>
<tr>
<td><strong>HEIGHT OF THE FIFTH WHEEL</strong></td>
<td>1.32m</td>
</tr>
<tr>
<td><strong>AMBIENT TEMPERATURE</strong></td>
<td>10°C</td>
</tr>
</tbody>
</table>
Baseline Configuration: A Train Double

Hendrickson Tractor, 4 Springs Trailer, 6 in
2 Springs Belly

- Rear Trailer Tandem Axles Load (High Side)
- Rear Trailer Tandem Axles Load (Low Side)
- Dolly Axle Load (High Side)
- Front Trailer Tandem Axles (High Side)

TABLE ANGLE (°)
Baseline Configuration: A Train Double

- Hendrickson Tractor
- 4 Springs Trailer 96 in.
- 2 Springs Belly
- Tractor Drive Axles Load (High Side)

Table Angle (R°)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

Load (lb)
DESCRIPTION

TRACTOR TYPE: 1975 Freightliner
TRAILER TYPE: 8-Train Flat Bed
TRACTOR LENGTH: 6.84 m
TRAILER LENGTH: 2 x 7.92 m
TIRE TYPE ON TRACTOR: Michelin Radial LR 24.5 X2A
TIRE TYPE ON TRAILERS: Michelin Radial LR 22.5 X2A
SUSPENSION TYPE ON TRACTOR: Hendrickson RTE 440
SUSPENSION TYPE ON FRONT TRAILER: 6 Springs (Tri axle)
SUSPENSION TYPE ON REAR TRAILER: 4 Springs Revco 21B
AXLE SPREAD ON TRACTOR: 2.47 m 1.35 m
AXLE SPREAD ON TRAILER: 1.62 m 1.32 m 4.92 m 1.79 m
TRACK WIDTH ON TRACTOR: 2.43 m
TRACK WIDTH ON TRAILER: 2.42 m
TIRE PRESSURE ADJUSTED TO: 100 psi
HEIGHT OF THE FIFTH WHEEL: 1.32 m
AMBIENT TEMPERATURE: 5°C
Baseline Configuration: B Train Double

- Hendrikse Tractor, 6 Springs Front Trailer 93 in
  4 Springs Rear Trailer
- Rear Trailer Tandem Axles Load (High Side)
- Rear Trailer Tandem Axles Load (Low Side)
- Front Trailer Third Axle (High Side)
- Front Trailer Tandem Axles (High Side)

TABLE ANGLE (R.°)
Baseline Configuration: B Train Double

Hendrickson Tractor, 6 Springs Front Trailer 96 in
4 Springs Rear Trailer

- Tractor Drive Axles Load (High Side)

TABLE ANGLE (R~)
T155

Task #1: Baseline Vehicles

Description

Tractor Type: 1975 Freightliner
Trailer Type: C-Train Flat Bed
Tractor Length: 6.84M
Trailer Length: 2*7.92M
Tire Type on Tractor: Michelin Radial 11R 24.5 XZA
Tire Type on Trailers: Michelin Radial 11R 22.5 XZA
Suspension Type on Tractor: Hendrickson KFE 440
Suspension Type on Trailers: 4 Springs Reyco 21B
Suspension Type on Dolly: 2 Springs Reyco 21B
Axle Spread on Tractor: 3.47M 1.85M
Axle Spread on Trailer: 1.24M 2.82M 4.94M 1.24M
Track Width on Tractor: 2.43M
Track Width on Trailer: 2.42M
Tire Pressure Adjusted to: 100 Psi
Height of the Fifth Wheel: 1.32M
Ambient Temperature: 13°C
Baseline Configuration: C Train Double

- Hendrickson Tractor, 4 Springs, Trailers 95 in
  - 2 Springs on Dolly
  - Rear Trailer Tandem Axles Load (High Side)
  - Rear Trailer Tandem Axles Load (Low Side)
  - Dolly Axle Load (High Side)
  - Front Trailer Tandem Axles (High Side)
DESCRIPTION

<table>
<thead>
<tr>
<th>ITEM</th>
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<tr>
<td>TRACTOR TYPE</td>
<td>1975 Freightliner</td>
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<tr>
<td>TRAILER TYPE</td>
<td>Ram 13,71M Flat Bed</td>
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<tr>
<td>TRACTOR LENGTH</td>
<td>6,84M</td>
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<td>TRAILER LENGTH</td>
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<tr>
<td>TIRE TYPE ON TRACTOR</td>
<td>Michelin Radial 11R 24.5 x2A</td>
</tr>
<tr>
<td>TIRE TYPE ON TRAILER</td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td>SUSPENSION TYPE ON TRACTOR</td>
<td>Hendrickson RTE 440</td>
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<tr>
<td>SUSPENSION TYPE ON TRAILER</td>
<td>Rayco 21E</td>
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<tr>
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<td>3,47M 1,35M</td>
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<tr>
<td>TRACK WIDTH ON TRACTOR</td>
<td>2,43M</td>
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<td>TIRE PRESSURE ADJUSTED TO</td>
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<tr>
<td>HEIGHT OF THE FIFTH WHEEL</td>
<td>1,32M</td>
</tr>
<tr>
<td>AMBIENT TEMPERATURE</td>
<td>20°C</td>
</tr>
</tbody>
</table>
Baseline Configuration: 5 Axles Trailer

- Hendrickson Tractor
- A. Springs Trailer 86 in
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Lead (kg)

TT49

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

TAPE ANG. F (R.)
Baseline Configuration: 5 Axles Trailer

- Hendrickson Tractor, 4 Springs Trailer 46 in
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

Table Angle (θ)

Tire Load (lbs)
### Task Two: Suspension Selection

#### DESCRIPTION

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Tractor Type</td>
<td>Inter F-9570</td>
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<tr>
<td>Trailer Type</td>
<td>14.78m Flat Bed</td>
</tr>
<tr>
<td>Tractor Length</td>
<td>8.02m</td>
</tr>
<tr>
<td>Trailer Length</td>
<td>14.78m</td>
</tr>
<tr>
<td>Rims Type on Tractor</td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td>Rims Type on Trailer</td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td>Suspension Type on Tractor</td>
<td>Hendrickson KTE 440</td>
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<td>Suspension Type on Trailer</td>
<td>Neway AR75</td>
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<td>5.12m 1.55m</td>
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<td>Axle Spread on Trailer</td>
<td>1.69m</td>
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<td>Track Width on Tractor</td>
<td>2.35m</td>
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<td>Track Width on Trailer</td>
<td>2.35m</td>
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<td>Tire Pressure Adjusted To</td>
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<tr>
<td>Height of the Fifth Wheel</td>
<td>1.22m</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>10°C</td>
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</table>
5.0 CONCLUSIONS

5.1 Validity of Tilt Table Test Procedure

The tilt table designed and built for the Vehicle Weights and Dimensions Study has been shown to be a valuable and effective tool for use in examining the roll stability of heavy, articulated commercial vehicles. It is relatively simple to operate, the tilt test procedure can be carried out relatively quickly, and provides a good deal of flexibility in terms of the amount and complexity of information which can be collected about the vehicle's behaviour as it progresses to rollover.

The tilt test simulates the forces which would be experienced by a vehicle which is progressing to rollover under steady state conditions. The track test equivalent dynamic manoeuvre is the constant radius turn at increasing speeds until rollover occurs. The rollover thresholds determined for a number of configurations subjected to both test procedures compared very favourably, leading to the conclusion that the tilt test is valid, and does provide a reasonable simulation of "real world" conditions (2).

It is recognised that steady state conditions rarely occur during the normal highway operation of heavy vehicles and that the introduction of additional transient dynamic forces will affect the roll threshold of the vehicle in service. Additional factors such as liquid slosh in tanker operations, suspended cargo such as hanging meat, and uneven load distribution on the trailer bed will also affect the roll stability of heavy vehicles. However, the static roll threshold as determined with the tilt table does provide a consistent basis for comparison of the inherent roll stability of one vehicle with another, and a basis for examining the effects on roll stability of geometric and parametric changes on a particular configuration.
suspension was also found to have a significant effect on the static roll threshold of the combination. For four different types of suspension currently offered to Canadian fleet operators, the observed range of static roll threshold for a tractor-trailer combination was 10%.

4. Trailer Suspension Choice

The resistance to roll provided by the trailer suspension was observed to have less influence on the roll threshold of the combination than the tractor suspension. Three different trailer suspensions were tested and an average variation on roll threshold of 5% was observed.

5. Fifth Wheel Vertical Slack

Removal of the vertical slack normally present between the fifth wheel and the trailer skid plate improved the roll threshold by about 4%.

6. Tire Choice

The test results did not reveal clear distinctions between the roll thresholds of tractor trailer combinations when the trailer axles were fitted with different tire types (bias ply, radial ply and low profile radial). There was an observable improvement when wide base single tires were substituted for duals, but this presumably was due to the increase in effective track width, and not attributable to tire construction.
Task Two: Suspension Selection (Loaded)

- Hendrickson Tractor, Neway Trailer
- Tractor Drive Axles Load (High Side)

TABLE ANGLE ($b_2$)
Task Two: Suspension Selection (Unloaded)

Hendrickson Tractor, Neary Trailer
- Trailer tandem axles, load (High Side)
- Trailer tandem axles, load (Low Side)

Load (kg)

Table Angle ($\theta_1$)
Task Two: Suspension Selection (unloaded)

Load (kg)

Henderson Tractor, Neway Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

Table Angle ($\theta_2$)
**Task Two: Suspension Selection**

**DESCRIPTION**

<table>
<thead>
<tr>
<th>TRACTOR TYPE</th>
<th>Inter F-9370</th>
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</thead>
<tbody>
<tr>
<td>TRAILER TYPE</td>
<td>14,78m Flat Bed</td>
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<tr>
<td>TRACTOR LENGTH</td>
<td>7,57m</td>
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<tr>
<td>TRAILER LENGTH</td>
<td>14,78m</td>
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<tr>
<td>TIRE TYPE ON TRACTOR</td>
<td>Michelin Radial 11R 22.5 x24</td>
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<tr>
<td>TIRE TYPE ON TRAILER</td>
<td>Michelin Radial 11R 22.5 x24</td>
</tr>
<tr>
<td>SUSPENSION TYPE ON TRACTOR</td>
<td>IH Air</td>
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<td>SUSPENSION TYPE ON TRAILER</td>
<td>Neway AR95</td>
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<tr>
<td>AXLE SPREAD ON TRACTOR</td>
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<td>AXLE SPREAD ON TRAILER</td>
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<td>AMBIENT TEMPERATURE</td>
<td>16°C</td>
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</table>
Task Two: Suspension Selection (Loaded)

- 17 Air Tractor, Narrow Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

**Table Angle** ($\theta_2$)
Task Two: Suspension Selection

(On Occas)

In All Tractor-Semitrailers:
- Tandem Axles Load High Side
- Tandem Axles Load Low Side

TABLE ANGLE ($\theta_1$)
Task Two: Suspension Selection (Unloaded)

- NH Air Tractor, Narrow, Trailer
  - Tractor Drive Axles Load (High Side)
  - Tractor Drive Axles Load (Low Side)

<table>
<thead>
<tr>
<th>Load (kg)</th>
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<tbody>
<tr>
<td>4500</td>
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<tr>
<td>4700</td>
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<tr>
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</tr>
<tr>
<td>1000</td>
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<td>500</td>
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<table>
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<td>36</td>
</tr>
<tr>
<td>38</td>
</tr>
<tr>
<td>40</td>
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TABLE ANGLE ($\theta_2$)
Task Two: Suspension Selection

DESCRIPTION

TRACTOR TYPE: Inter F-9370
TRACTOR LENGTH: 7.72M
TRAILER TYPE: 14.78M Flat Bed
TRAILER LENGTH: 14.78M
TIRES TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZA
TIRES TYPE ON TRAILER: Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR: 1H 4 Springs
SUSPENSION TYPE ON TRAILER: Neway AR95
AXLE SPREAD ON TRACTOR: 4.96M J, 4CM
AXLE SPREAD ON TRAILER: 1.69M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.35M
TIRES PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1.02M
AMBIENT TEMPERATURE: 10°C
Task Two: Suspension Selection

(Loaded)

TABLE ANGLE (θ₁)
Task Two: Suspension Selection (Loaded)

- [Graph showing load vs. table angle for different scenarios]

- High Spring Tractor, Mecay Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)
Task Two: Suspension Selection (Unloaded)
Task Two: Suspension Selection

DESCRIPTION

TRACTOR TYPE: Interm F-9170
TRAILER TYPE: 14,78M Flat Bed
TRACTOR LENGTH: 7,79M
TRAILER LENGTH: 14,78M
TIRE TYPE ON TRACTOR: Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER: Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR: Neway ARV244
SUSPENSION TYPE ON TRAILER: Neway AR95
AXLE SPREAD ON TRACTOR: 4,85M 1,55M
AXLE SPREAD ON TRAILER: 1,69M
TRACK WIDTH ON TRACTOR: 2,40M
TRACK WIDTH ON TRAILER: 2,05M
TIRE PRESSURE ADJUSTED TO: 100 Psi
HEIGHT OF THE FIFTH WHEEL: 1,25M
AMBIENT TEMPERATURE: 16°C
Task Two: Suspension Selection (Loaded)

- Neway Tractor, Neway Trailer
- Trolley Tandem Axles Load (High Side)
- Trolley Tandem Axles Load (Low Side)

TABLE ANGLE ($\theta_1$)
Task Two: Suspension Selection

(Loaded)

- Neway Tractor, Neway Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

TABLE ANGLE ($\theta_2$)
Task Two: Suspension Selection
(Unloaded)

- Traction Axles
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Load [Kg]

Table Angle (θ_i)
Task Two: Suspension Selection
(Unloaded)

Neway Tractor, Neway Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)
Task Two: Suspension Selection

DESCRIPTION

TRACTOR TYPE: Inter F-9370
TRACTOR TYPE ON TRACTOR: Michelin Radial 1IR 22.5 x2A
TRACTOR LENGTH: 7.79m
TRAILER LENGTH: 14.78m
TRAILER TYPE: 14,78m Flat Bed
TRAILER TYPE ON TRAILER: Michelin Radial 1IR 22.5 x2A
SUSPENSION TYPE ON TRACTOR: Neway 4RD 244
SUSPENSION TYPE ON TRAILER: Reyco 21D
AXLE SPREAD ON TRACTOR: 4.85m 1.65m
AXLE SPREAD ON TRAILER: 1.65m
TRACK WIDTH ON TRACTOR: 2.40m
TRACK WIDTH ON TRAILER: 2.35m
TIRE PRESSURE ADJUSTED TO: 100 psi
HEIGHT OF THE FIFTH WHEEL: 1.25m
AMBIENT TEMPERATURE: 10°C
Task Two: Suspension Selection

(Loaded)

- Hayy Tractor
- Recco Trailer
- Tractor Tandem Axles Load (High Side)
- Tractor Tandem Axles Load (Low Side)

D

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

TABLE ANGLE \( \theta \degree \)
Task Two: Suspension Selection (Loaded)
Task Two: Suspension Selection (Unloaded)

- Heavy Tractor-Semitrailer
- Trailer Tandem Axles Load High Side
- Trailer Tandem Axles Load Low Side

Load (KG)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

Table Angle ($\theta_1$)
Task Two: Suspension Selection
(Unloaded)

- Neway Tractor, Reeco Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

TABLE ANGLE (θ>)}
**Task Two: Suspension Selection**

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
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<tbody>
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<td>TRACTOR TYPE</td>
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<tr>
<td>TIRE TYPE ON TRACTOR</td>
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</tr>
<tr>
<td>TIRE TYPE ON TRAILER</td>
<td>Michelin Radial 11R 22.5 XZA</td>
</tr>
<tr>
<td>SUSPENSION TYPE ON TRACTOR</td>
<td>Hendrickson RTE 440</td>
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<tr>
<td>SUSPENSION TYPE ON TRAILER</td>
<td>Chalmers 700</td>
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<tr>
<td>AXLE SPREAD ON TRACTOR</td>
<td>5,1cm 1,55m</td>
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<tr>
<td>AXLE SPREAD ON TRAILER</td>
<td>1,69m</td>
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<tr>
<td>TRACK WIDTH ON TRACTOR</td>
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<tr>
<td>TIRE PRESSURE ADJUSTED TO</td>
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<tr>
<td>HEIGHT OF THE FIFTH WHEEL</td>
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<td>AMBIENT TEMPERATURE</td>
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</table>
Task Two: Suspension Selection (Loaded)

TABLE ANGLE ($\theta$) vs Load (Kg) for different types of equipment:
- Farm Tractor
- Tractor Tandem Axles Load (High Side)
- Tractor Tandem Axles Load (Low Side)
- Chalmers Tractor Tandem Axles Load

Graph shows the relationship between load and angle for various tractor types.
Task Two: Suspension Selection (Loaded)

- Hendrickson Tractor-Drawers (trailer)
- Tractor Drive Axles (load - high side)
- Tractor Drive Axles (load - low side)

TABLE ANGLE (θ°)
Task Two: Suspension Selection

(Unloaded)

- Hendrickson Tractor, Chalmers Trailer
  - Trailer Tandem Axles Load (High Side)
  - Trailer Tandem Axles Load (Low Side)

Table Angle ($\theta_1$)
Task Two: Suspension Selection
(Unloaded)

- Hendrickson Tractor, Chalmers Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

Load (Kg)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

Table Angle ($\theta$)
Task Two: Suspension Selection

DESCRIPTION

TRACTOR TYPE: Inter F-937U
TRACTOR LENGTH: 7.37M
TRAILER TYPE: 14,78M Flat Bed
TRAILER LENGTH: 14.78M
TIRE TYPE ON TRACTOR: Michelin Radial 1LR 22.5 X2A
TIRE TYPE ON TRAILER: Michelin Radial 1LR 22.5 X2A
SUSPENSION TYPE ON TRACTOR: IH Air
SUSPENSION TYPE ON TRAILER: Chalmers 700
AXLE SPREAD ON TRACTOR: 4.68M 1.52M
AXLE SPREAD ON TRAILER: 1.69M
TRACK WIDTH ON TRACTOR: 2.40M
TRACK WIDTH ON TRAILER: 2.35M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1.21M
AMBIENT TEMPERATURE: 5°C
Task Two: Suspension Selection (Loaded)

- IH Air tractor, drawbar load
- IH tractor, drawbar load (High Side)
- Tractor drive axles load (High Side)
- Tractor drive axles load (Low Side)

TABLE ANGLE (θ°)
Task Two: Suspension Selection
(Unloaded)

IH Air, Tractor, Chalmers, Tractor
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)

Load (kg)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

TABLE ANGLE ($\theta_1$)
Task Two: Suspension Selection
(Unloaded)

- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)
- If Air Tractor Chalmers Trailer

TABLE ANGLE ($\theta_d$)
**Task Two: Suspension Selection**

**DESCRIPTION**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Details</th>
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<tr>
<td>TRAILER TYPE</td>
<td>14.78M Flat Bed</td>
</tr>
<tr>
<td>TRACTOR LENGTH</td>
<td>7.72M</td>
</tr>
<tr>
<td>TRAILER LENGTH</td>
<td>14.78M</td>
</tr>
<tr>
<td>TIRE TYPE ON TRACTOR</td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td>TIRE TYPE ON TRAILER</td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td>SUSPENSION TYPE ON TRACTOR</td>
<td>1H 4 Springs</td>
</tr>
<tr>
<td>SUSPENSION TYPE ON TRAILER</td>
<td>Chalmers 700</td>
</tr>
<tr>
<td>AXLE SPREAD ON TRACTOR</td>
<td>4.96M 1.32M</td>
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<tr>
<td>AXLE SPREAD ON TRAILER</td>
<td>1.69M</td>
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<tr>
<td>TRACK WIDTH ON TRACTOR</td>
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<td>TRACK WIDTH ON TRAILER</td>
<td>2.25M</td>
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<tr>
<td>TIRE PRESSURE ADJUSTED TO</td>
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<tr>
<td>HEIGHT OF THE FIFTH WHEEL</td>
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<td>AMBIENT TEMPERATURE</td>
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</table>
Task Two: Suspension Selection (Loaded)

IH 4 Spring Tractor, Chalmers Tractor

Trailer Tandem Axle Load (High Side)

Trailer Tandem Axle Load (Low Side)

TABLE ANGLE ($\theta$)
Task Two: Suspension Selection
(Unloaded)

- H C Springs Tractor, Chalmers Trailer
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

TABLE ANGLE ($\theta$)
### DESCRIPTION

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
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<tr>
<td>Trailer Type</td>
<td>14.78-m Flat Bed</td>
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<tr>
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<tr>
<td>Trailer Length</td>
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<tr>
<td>Tire Type on Tractor</td>
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<tr>
<td>Tire Type on Trailer</td>
<td>Michelin Radial 11R 22.5 x 24</td>
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<tr>
<td>Suspension Type on Tractor</td>
<td>Neway ARD 244</td>
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<tr>
<td>Suspension Type on Trailer</td>
<td>Chalmers 700</td>
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<tr>
<td>Axle Spread on Trailer</td>
<td>1.69 m</td>
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<tr>
<td>Track Width on Tractor</td>
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<tr>
<td>Track Width on Trailer</td>
<td>7.35 m</td>
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</table>
Task Two: Suspension Selection (Loaded)

- Kenay Tractor: Chalmers, Ford
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

TABLE ANGLE ($\theta_j$)
Task Two: Suspension Selection (Unloaded)

New Tractor, Chalmers Trailer
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

TABLE ANGLE ($\theta_1$)
Task Two: Suspension Selection
(Unloaded)

Neway Tractor, Chainring Trailer
--- Tractor Drive Axles Load (High Side)
--- Tractor Drive Axles Load (Low Side)

TABLE ANGLE (α°)
### Task Two: Suspension Selection

**DESCRIPTION**

<table>
<thead>
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<th>Parameter</th>
<th>Specification</th>
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<tr>
<td>Trailer Type</td>
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<td>Tractor Length</td>
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<tr>
<td>Trailer Length</td>
<td>14,78m</td>
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<tr>
<td>Tire Type on Tractor</td>
<td>Michelin Radial L1R 22.5 XZA</td>
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<tr>
<td>Tire Type on Trailer</td>
<td>Michelin Radial L1R 22.5 XZA</td>
</tr>
<tr>
<td>Suspension Type on Tractor</td>
<td>Hendrickson RTE 440</td>
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<tr>
<td>Suspension Type on Trailer</td>
<td>Reyco 218</td>
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<tr>
<td>Axle Spread on Tractor</td>
<td>5,12m 1,55m</td>
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<tr>
<td>Axle Spread on Trailer</td>
<td>1,70m</td>
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<tr>
<td>Track Width on Tractor</td>
<td>2,25m</td>
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<tr>
<td>Track Width on Trailer</td>
<td>2,25m</td>
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<tr>
<td>Tire Pressure Adjusted To</td>
<td>100 Psi</td>
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<tr>
<td>Height of the Fifth Wheel</td>
<td>1,57m</td>
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<tr>
<td>Ambient Temperature</td>
<td>10°c</td>
</tr>
</tbody>
</table>

T112,19
Task Two: Suspension Selection
(loaded)

Table Angle ($\theta$)
Task Two: Suspension Selection (Loaded)

- Hendrickson Tractor, Reyco Trailer
- Tractor Drive Axles Loaded High Side
- Tractor Drive Axles Loaded Low Side

TABLE ANGLE ($\theta$)
Task Two: Suspension Selection
(Unloaded)

- Hendrickson Tractor-Royal Trailer
- Trailer Tandem Axles (Low Side)
- Trailer Tandem Axles (High Side)

Load (Kg)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

Table Angle (θ)

12

5000 4500 4000 3500 3000 2500 2000 1500 1000 500 0
Task Two: Suspension Selection (Unloaded)

- Henrichsen Tractor, Rayce Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

TABLE ANGLE (θ)

Load (kg)
Task Two: Suspension Selection

**DESCRIPTION**

TRACTOR TYPE: Inter F-9170

TRAILER TYPE: 14,78M Flat Bed

TRACTOR LENGTH: 7.57M

TRAILER LENGTH: 14.78M

TIRES TYPE ON TRACTOR: Michelin Radial 11R 22.5 X2A

TIRES TYPE ON TRAILER: Michelin Radial 11R 22.5 X2A

SUSPENSION TYPE ON TRACTOR: Air

SUSPENSION TYPE ON TRAILER: Reyco 21B

AXLE SPREAD ON TRACTOR: 4.80M 1.32M

AXLE SPREAD ON TRAILER: 1.69M

TRACK WIDTH ON TRACTOR: 2.40M

TRACK WIDTH ON TRAILER: 2.35M

TIRES PRESSURE ADJUSTED TO: 100 psi

HEIGHT OF THE FIFTH WHEEL: 1.22M

AMBIENT TEMPERATURE: 10°C
Task Two: Suspension Selection (Loaded)

TABLE ANGLE ($\theta$)

- THM Tractor, Tandem Axles Load (High Side)
- Tandem Axles Load (Low Side)
Task Two: Suspension Selection (Loaded)
Task Two: Suspension Selection
(Unloaded)

IH Air Tractor, Beyco Trailer
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Load (kg)

TABLE ANGLE (θ°)
Task Two: Suspension Selection
(Unloaded)

Load (kg)

In Air Tractor, Rayco Trailer

- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)
**DESCRIPTION**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td><strong>TRACTOR TYPE</strong></td>
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<tr>
<td><strong>TRAILER TYPE</strong></td>
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<td><strong>TRAILER LENGTH</strong></td>
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<td><strong>TIRE TYPE ON TRACTOR</strong></td>
<td>Michelin Radial 11R 22.5 x2A</td>
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<tr>
<td><strong>TIRE TYPE ON TRAILER</strong></td>
<td>Michelin Radial 11R 22.5 x2A</td>
</tr>
<tr>
<td><strong>SUSPENSION TYPE ON TRACTOR</strong></td>
<td>IM 4 Springs</td>
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<tr>
<td><strong>SUSPENSION TYPE ON TRAILER</strong></td>
<td>Reyco 21B</td>
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<td><strong>AXLE SPREAD ON TRACTOR</strong></td>
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<td><strong>AXLE SPREAD ON TRAILER</strong></td>
<td>1,70m</td>
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<td><strong>TRACK WIDTH ON TRACTOR</strong></td>
<td>2,37m</td>
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<td><strong>TRACK WIDTH ON TRAILER</strong></td>
<td>2,35m</td>
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<tr>
<td><strong>TIRE PRESSURE ADJUSTED TO</strong></td>
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<tr>
<td><strong>HEIGHT OF THE FIFTH WHEEL</strong></td>
<td>1,22m</td>
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<tr>
<td><strong>AMBIENT TEMPERATURE</strong></td>
<td>10°C</td>
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</tbody>
</table>
Task Two: Suspension Selection
(Loaded)

- Tractor Tandem Axles Load (High Side)
- Tractor Tandem Axles Load (Low Side)

Table Angle (θ°)
Task Two: Suspension Selection
(Loaded)

- 18.4 Spring Tractor, Heavy Trailer
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

TABLE ANGLE (θ - )
Task Two: Suspension Selection
(Unloaded)

TI 4 Spring Tractor, kayco Trailer
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Load (Kg)
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000

Table Angle ($\theta_1$)
Task: Three: All Tires Selection

DESCRIPTION

TRACTOR TYPE____________________: Inter F-9370
TRAILER TYPE___________________: 14.73M Flat Bed
TRACTOR LENGTH_______________: 7.72M
TRAILER LENGTH_______________: 14.73M
TIRE TYPE ON TRACTOR_________: Michelin Radial 11R 22.5 12L
SUSPENSION TYPE ON TRACTOR_____: IH 4 Springs
SUSPENSION TYPE ON TRAILER_____: McKay 21B
AXLE SPREAD ON TRACTOR_________: 4.96M 1.37M
AXLE SPREAD ON TRAILER_________: 1.70M
TRACK WIDTH ON TRACTOR_______: 2.27M
TRACK WIDTH ON TRAILER________: 2.25M
TIRE PRESSURE ADJUSTED TO______: 100 PSI
HEIGHT OF THE FIFTH WHEEL______: 1.22M
AMBIENT TEMPERATURE___________: 10°C
Task Three: (c) Tires Selection (Loaded)

- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

Tractor: 8 Spring Tractor; Revoch, Tractor 96 in
Trailer Tire: Michelin 16.5R22.5 745-34

Load (Kg) vs. TIRE ANGLE (°)
Task Three: a) Tires Selection
(Unloaded)

IH 4 Spring Tractor, Reyon Trailer 96 in
Trailer: Time Michelin 16.5R22.5 XM-84

- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

<table>
<thead>
<tr>
<th>Load (kg)</th>
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<tbody>
<tr>
<td>5000</td>
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<tr>
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<tr>
<td>1000</td>
</tr>
<tr>
<td>500</td>
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<tr>
<td>0</td>
</tr>
</tbody>
</table>

Table Angle ($\theta$)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Task Three (c) Tires Selection
(Unloaded)

IH 3 Springs Tractor, Kenworth Tractor, 96 in
Trailer Tire. Michelin 16.5R22.5 KH-54

- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

TABLE ANGLE (θ)
Task Three: a) Tires Selection (Loaded)

- 8.4 Spring tractor, Michelin TIR 22.5/11R
- Tandem Axles Load (High Side)
- Tandem Axles Load (Low Side)

TABLE ANGLE ($\theta$)
Task Three: a) Tires Selection (Loaded)

- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)
Task Three: a) Tires Selection (Unloaded)

- LH 1 Springs Traction, 75p. Tires
- Trailer Tires: Michelin LR 22.5 x 9.5

---

- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Load (kg)

TABLE ANGLE (\theta_i)
Task Three: a) Tires Selection (Unloaded)

Tractor Drive Axles Load (High Side)
Tractor Drive Axles Load (Low Side)

Hi-Spring Tractor, Hayes Trailer 96 in.
Trailer Tire: Michelin X3 22.5 X2A

Load (kg)

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

TIRE ANGLE (B°)
Task Three: a) Tires Selection (Loaded)

- 16.2 Spring Tractor, Rigid Trailer 96 in.
- Trailer Tire: Michelin 275/80R 22.5 Pilot AX
- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)

Table Angle (°)
Task Three: Tire Selection (Unloaded)

- 14-Springer, Tractor, Pneu. Tread - 65 x 2
- Tractor Tire: Michelin 275/80R 22.5, P500 XA
- Trailer Tandem Axles, Lead (High Side)
- Trailer Tandem Axles, Lead (Low Side)

Load (lbs)

Table Angle (°)
Task Three: Tire Selection (Unloaded)

- INI & Simpsons Tractor, Revers-Fuller 96 in.
- Trailer Tire: Michelin 275/80R 22.5, Plate WA

- Tractor Drive Axle Low (High Side)
- Tractor Drive Axle Low (Low Side)

TABLE ANGLE (°)
Task Three: (c) Tires Selection

(Loaded)

- 4 Spring Tractor, Besco Trailer 86 in.
- Trailer Tire: Good Year Super M-Killer 10.00-20
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

LOAD (Kg)

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

TIRE ANGLE (A.)
Task Three: a) Tires Selection

2. Tires: Firestone 16 in.
3. Tires: Goodyear 16 in.
4. Tires: Cooper 16 in.

Note: Tire size and type may vary depending on specific load and terrain conditions.
Task Three: (a) Tires Selection

DESCRIPTION

TRACTOR TYPE: Inter F-9270
TRAILER TYPE: 14.78M Flat Bed
TRACTOR LENGTH: 7.72M
TRAILER LENGTH: 14.76M
TIRE TYPE ON TRACTOR: Michelin Radial LR 32.5 x2A
SUSPENSION TYPE ON TRACTOR: IH 4 Springs
SUSPENSION TYPE ON TRAILER: Reyco 21B
AXLE SPREAD ON TRACTOR: 4.96M 1.32M
AXLE SPREAD ON TRAILER: 1.70M
TRACK WIDTH ON TRACTOR: 2.37M
TRACK WIDTH ON TRAILER: 2.51M
TIRE PRESSURE ADJUSTED TO: 100 PSI
HEIGHT OF THE FIFTH WHEEL: 1.22M
AMBIENT TEMPERATURE: 10°C
Task Three: (a) Tires Selection (Loaded)

- M & A Spring Tractor
  - Reyco Trailer 102 in
  - Trailer Tire Michelin 10.00-22.5 M/S

- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)
Task Three: (a) Tires Selection (Loaded)

- In 4 Spring Traction Kegco Trailer 102 in.
- Tractor Tire Sizes: 16.9R22.5 XW94
- Tractor Drive Axles: Load (High Side)
- Tractor Drive Axles: Load (Low Side)
Task Three: a) Tires Selection (unloaded):

- 4 Spring Tractor Road: Tractor 12 in.
- Trailer Tires: Michelin AS TR 22.5 LCA

- Trailer Tandem Axles Lead (high side)
- Trailer Tandem Axles Lead (low side)
Task Three: a) Tires Selection (Loaded)

In 4 Spring Tractor, Mayde Trailer 102 in
Trailer Tire Michelin 11R 22.5 XLA

- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

TIRE ANGLE (R.)

Load (Kg)
Task Three: a) Tire Selection (Loaded)

- Hi-C Spring Tractor, Bescor Trailer, 102 in.
- Tractor Tire: Michelin UTR 22.5 XZA
- Tractor Drive Axle Load (High Side)
- Tractor Drive Axle Load (Low Side)
Task Three: a) Tires Selection
(Unloaded)

IH 4-114 Tractor, Kenne-Wray, Tractor 102 in.
Trailer tires: Michelin TLR 22.5 x 24

- Trailer tandem axles load (high side)
- Trailer tandem axles load (low side)

TABLE ANGLE (θ)
Task Three: a) Tires Selection
(Unloaded)

[H & Springs Tractor, Raygo Trailer 102"
Trailer Tire, Michelin LTR 22.5"

--- Tractor Drive Axles Load (High Side)
--- Tractor Drive Axles Load (Low Side)

TABLE ANGLE (θ°)
Task Three: a) Tire Selection (Loaded)

- 10 x 16.5 Toyo Tires
- 11R16.5 Toyo Tires
- 11R16.5 Michelin
- 11R16.5 Firestone

Truck Tandem Axles Load (High Side)
Truck Tandem Axles Load (Low Side)

Top Angle (A)
Task Three: d) Tires Selection (Unloaded)

- Hays Springs Tractor, Royal Tire 102cr
- Trailer Tire Michelin 275/80R 22.5 Pilothe KA

- Tractor Drive Axle (High Side)
- Tractor Drive Axle (Low Side)

TABLE ANGLE (θ)

Load (lbs)
Task Three: a) Tires Selection (Loaded)

- IH 4-Spring Tractor, Goodyear, 102 in.
- Trailer Tires: Good Year Super 4-W, Kinkel 10.00-20
  - Trailer Tandem Axles Load (High Side)
  - Trailer Tandem Axles Load (Low Side)

Table Angle (R.)
Task Three: (c) Tires Selection

(Loaded)

- High Spring Tractor-Reyn Trailer 102 in
  - Tractor Tire Load Year Super II Holder 10.00-20
  - Tractor Drive Axles Load (High Side)
  - Tractor Drive Axles Load (Low Side)

TIRE ANGLE (R°)
Task Three: Tires Selection
(Unloaded)

H-4 Springs Tractor, Revers, Trailer 10-20
Trailer Tires
Load Year: Super 11-Wheel 10, 00-20

- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Load (Kg)

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

TIRE ANGLE (DEG.)
Task Three: 2) Tires Selection
(Unloaded)

- 10,000 lbs
- 9,000 lbs
- 8,000 lbs
- 7,000 lbs
- 6,000 lbs
- 5,000 lbs
- 4,000 lbs
- 3,000 lbs
- 2,000 lbs
- 1,000 lbs
- 500 lbs
- 0 lbs

- Tractor Drive Axles Load (High Side)
- Tractor Drive Axles Load (Low Side)
- Trailer Tires Good Year Super H-Miler (10.00-20)
-.UserInfo: Springs Tractor, Reysa Trailer 100 in.

NOTE: 
- Measure to the Centimeter
- 0.125 cm
**DESCRIPTION**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td><strong>TRACTOR TYPE</strong></td>
<td>Intert F-7570</td>
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<tr>
<td><strong>TRAILER TYPE</strong></td>
<td>14,79M Flat Bed</td>
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<tr>
<td><strong>TRACTOR LENGTH</strong></td>
<td>7,72M</td>
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<tr>
<td><strong>TRAILER LENGTH</strong></td>
<td>14,79M</td>
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<tr>
<td><strong>TIRE TYPE ON TRACTOR</strong></td>
<td>Michelin Radial 11R 22.5 XZM</td>
</tr>
<tr>
<td><strong>SUSPENSION TYPE ON TRACTOR</strong></td>
<td>1H 4 Springs</td>
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<tr>
<td><strong>SUSPENSION TYPE ON TRAILER</strong></td>
<td>Rayco 21B</td>
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<tr>
<td><strong>AXLE SPREAD ON TRACTOR</strong></td>
<td>4,96M 1,32M</td>
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<tr>
<td><strong>AXLE SPREAD ON TRAILER</strong></td>
<td>1,70M</td>
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<tr>
<td><strong>TRACK WIDTH ON TRACTOR</strong></td>
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<tr>
<td><strong>TRACK WIDTH ON TRAILER</strong></td>
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<tr>
<td><strong>TIRE PRESSURE ADJUSTED TO</strong></td>
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<tr>
<td><strong>HEIGHT OF THE FIFTH WHEEL</strong></td>
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<tr>
<td><strong>Ambient Temperature</strong></td>
<td>10°C</td>
</tr>
</tbody>
</table>
Task Three: Fifth Wheel Vertical Slack (Loaded)

Fifth Wheel Vertical Slack
- Spring Tractor, Revo Tandem Axle Load (High Side)
- Trailer, Tandem Axle Load (Low Side)
Task Three: Relationship of Fifth Wheel Vertical Slack to Load (Loaded)

Fifth Wheel Slack vs Load (Kgf)
- Tractor-Drive Axles Load (High Side)
- Tractor-Drive Axles Load (Low Side)

Table Angle (°)
Task Three: b) Fifth Wheel Vertical Slack
(Unloaded)

IH 4 Springs Tractor, Rayco Trailer 98 in
Fifth Wheel Vertical Slack No Slack

- Trailer Tandem Axles Load High Side
- Trailer Tandem Axles Load Low Side

Table and Fig.

Load (Kg)

TT32

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Task Three: b) Fifth Wheel Vertical Slack
(Loaded)

Tandem Axle Load (High Side)
Tandem Axle Load (Low Side)

Load (KG)

TABLE ANGLE (R.)
Task Three: 2) Fifth Wheel Vertical Slack (Loaded)

- Spring Tractor/Reyno Trailer 95 in
- Fifth Wheel Vertical Slack 1/2 Slack
- Traction Drive Axles Load (High Side)
- Traction Drive Axles Load (Low Side)

Table Angle (θ°)
Task Three: b) Fifth Wheel Vertical Slack
(Unloaded)

IH 4 Springs Tractor, Rayco Trailer 95 in.
Fifth Wheel Vertical Slack 1/2 Slack
- Trailer Tandem Axles Load (High Side)
- Trailer Tandem Axles Load (Low Side)

Table: ANCF (Ft.)

Load (Kg)
Task Three: b) Fifth Wheel Vertical Slack (Unloaded)