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

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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 Quebec 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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Vehicle Weights and Dimensions Study

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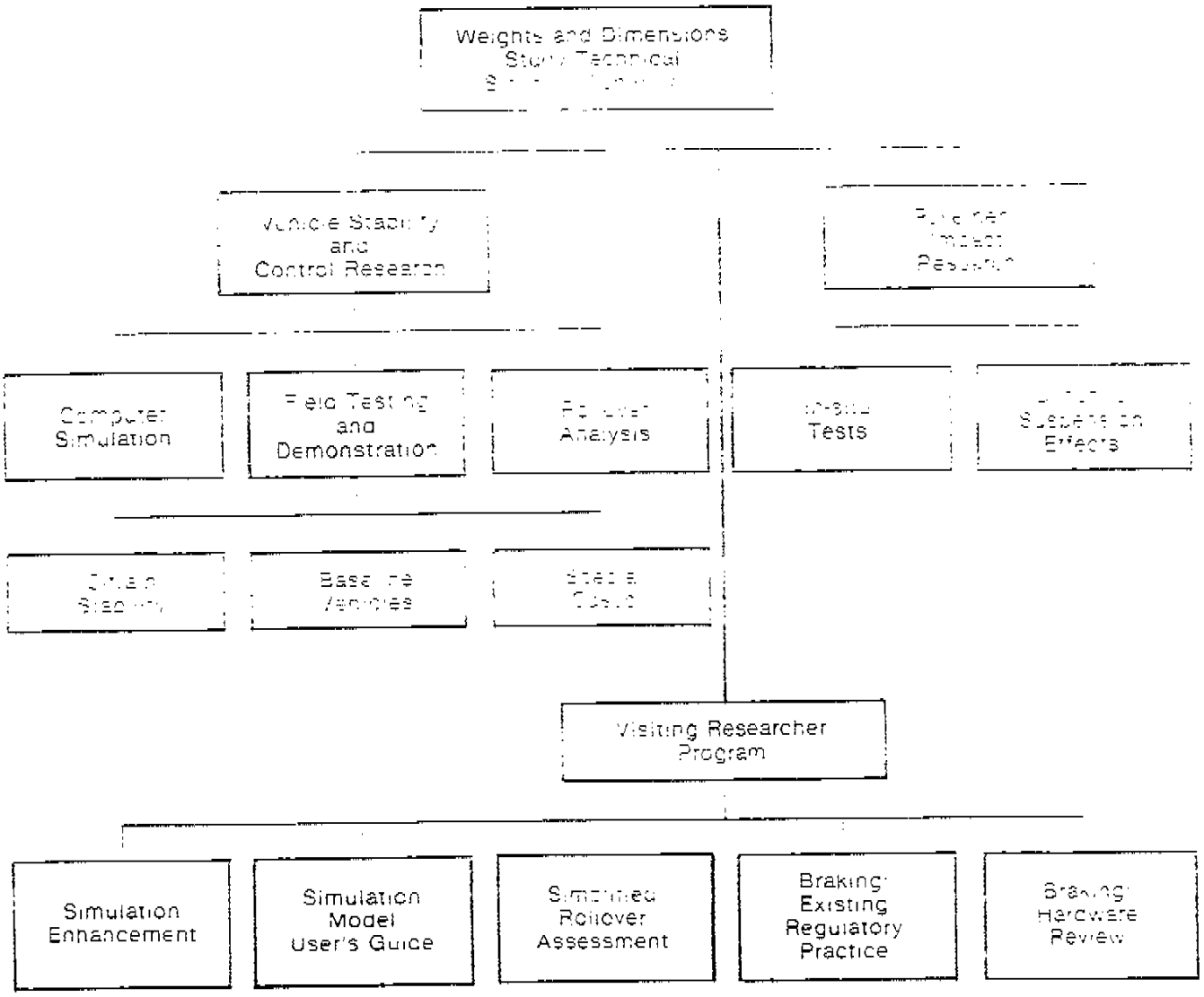
HEAVY VEHICLE WEIGHTS AND DIMENSIONS STUDY

TECHNICAL WORK ELEMENTS OVERVIEW



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 roll 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

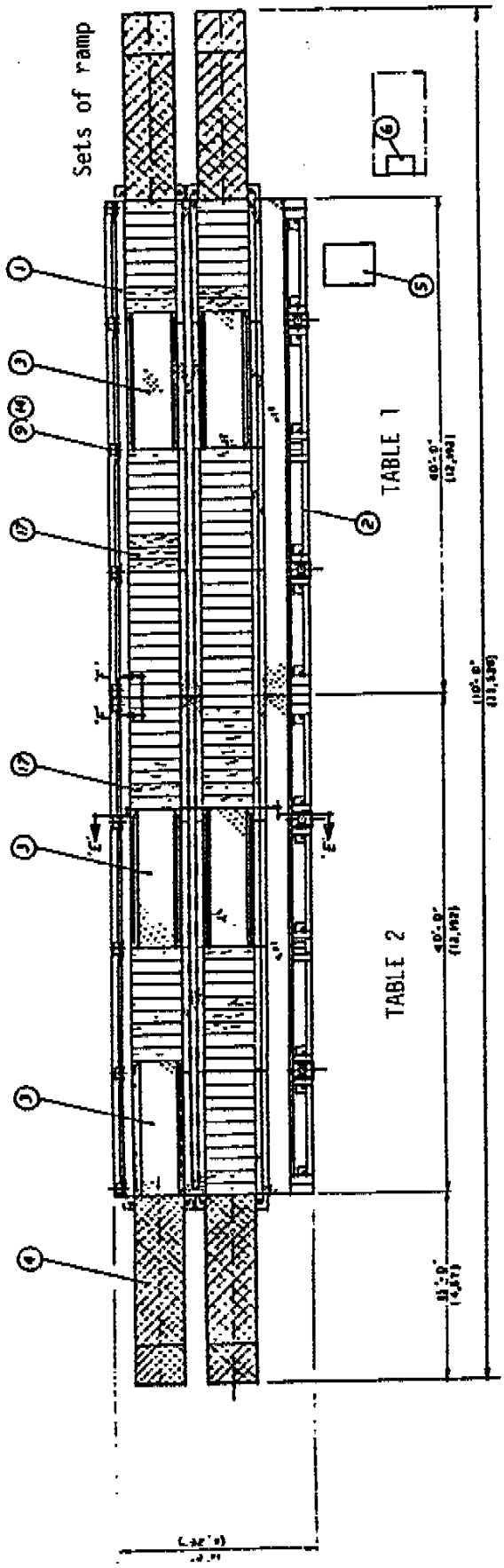
2.1 Design, Construction and Capabilities

A tilt table is a device used to determine the roll-over 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

TILT TABLE ASSEMBLY



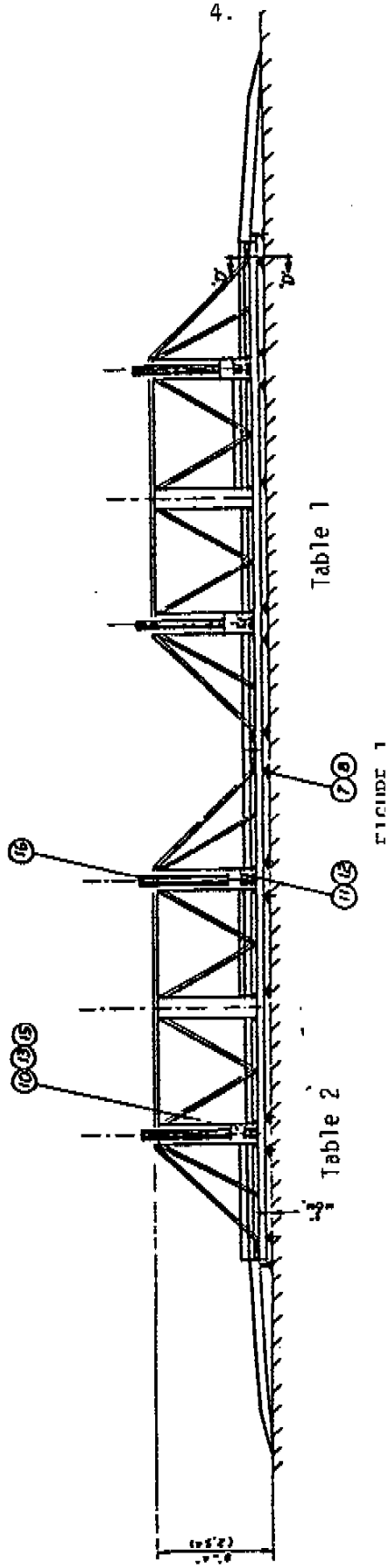


FIGURE 1

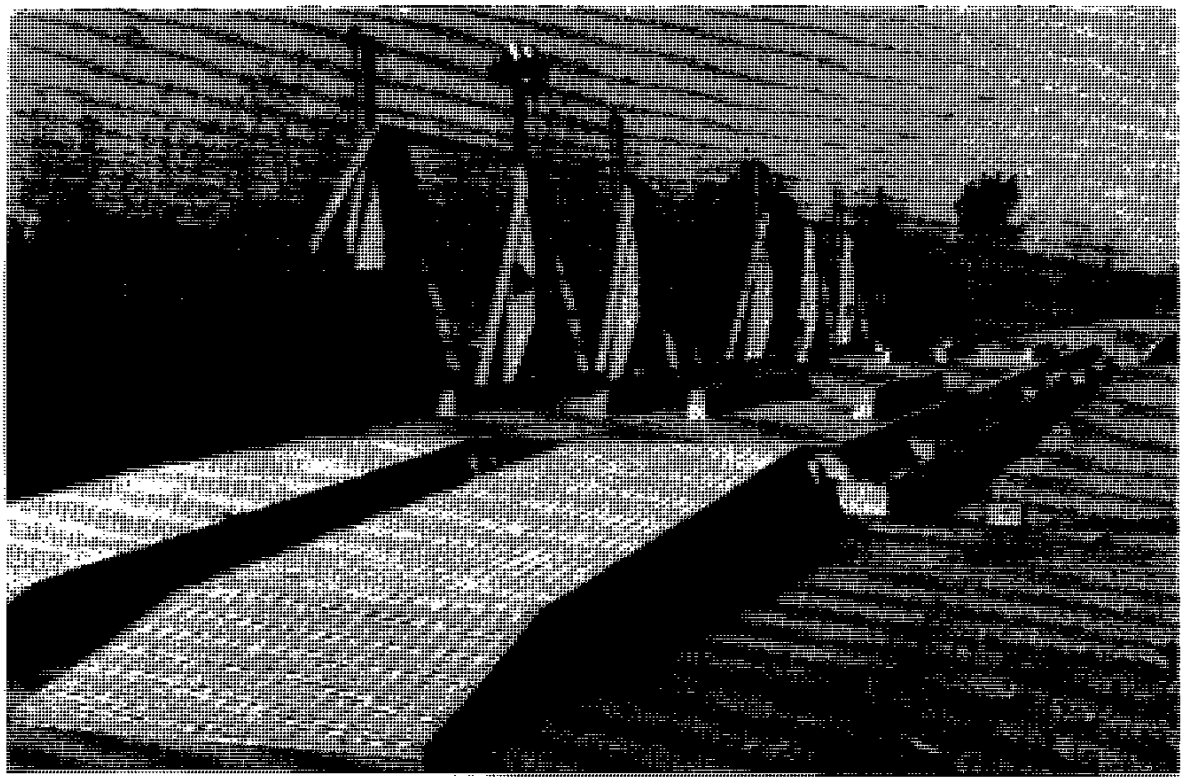


FIGURE 2

TILT TABLE PHOTO

latter a unit extremely resistant to flexion. On the cylinder side, tubes are provided to form a stiff plane that switches 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)[1]. 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 approximatively 15 to 30 degrees per minute. The lowering speed is independently adjustable and varies of 15 degrees or less per minute.

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[1] The maximum load is function of its location on each platform.

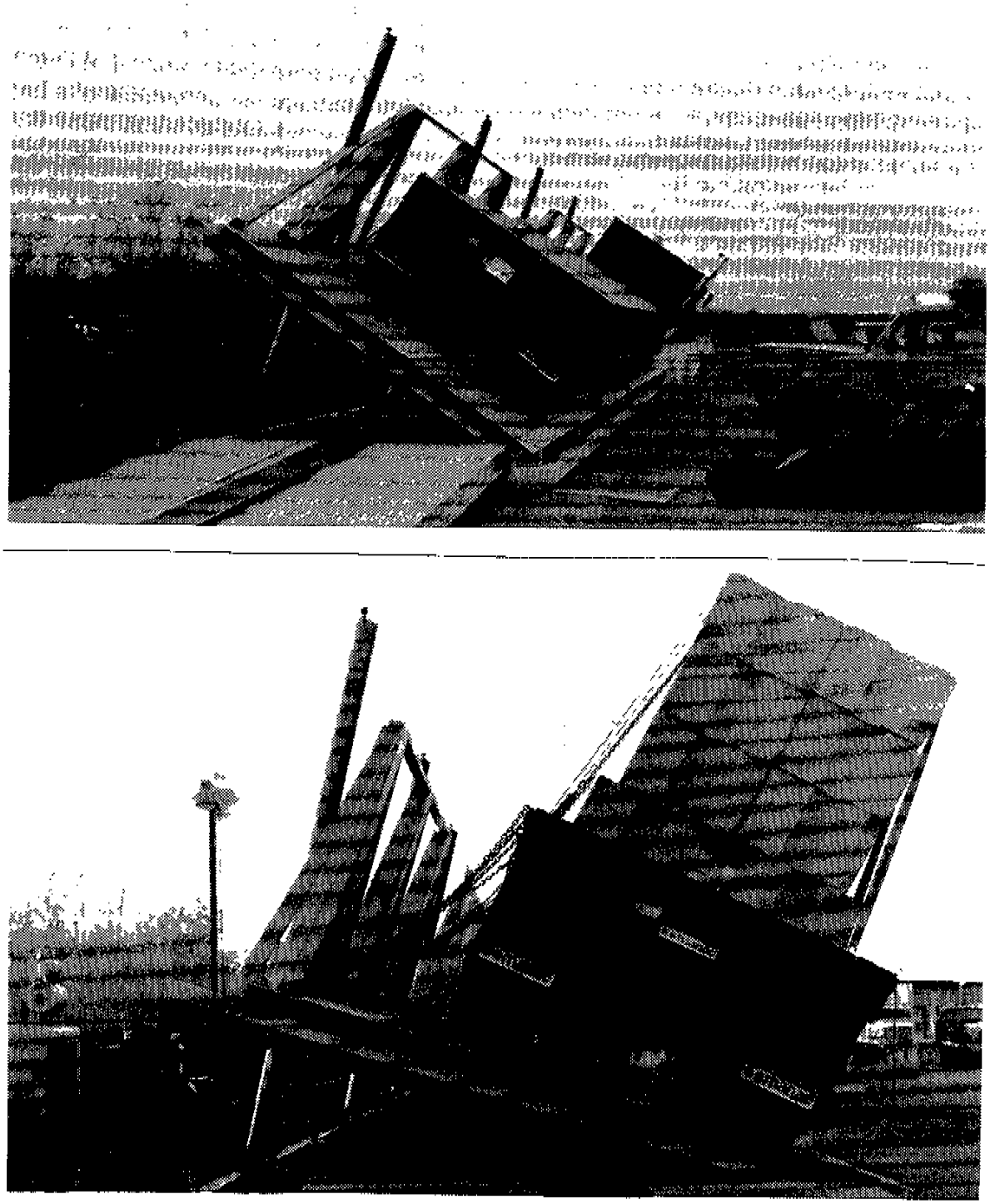


FIGURE 3

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

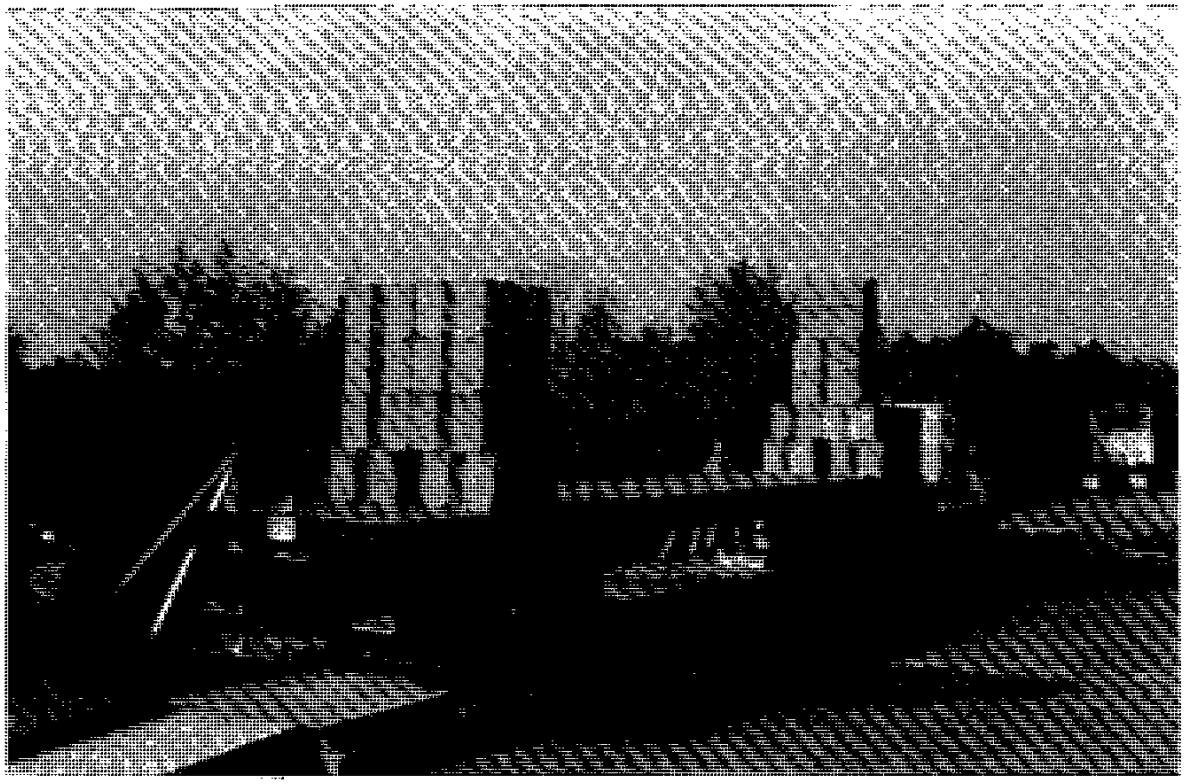
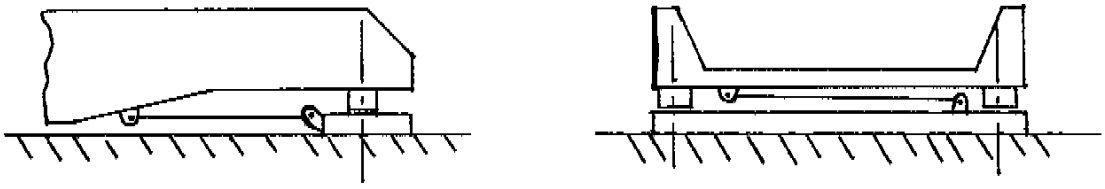


FIGURE 6.

LOAD ARRANGEMENT

2.2 Instrumentation and Data Acquisition

The tilt table has five weight-measuring pads which can be moved to accomodate 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 $\pm$ 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:

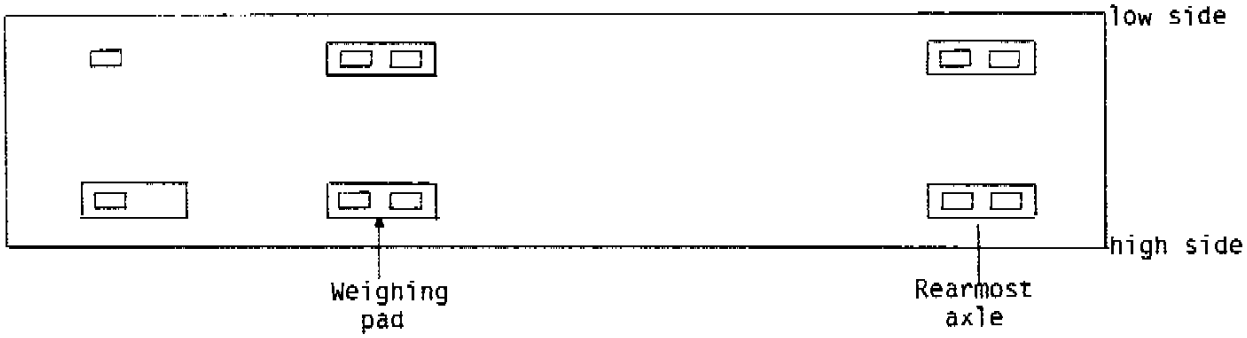
- Test Series One: Influence of Center of Gravity Height
- Test Series Two: Influence of Tractor Suspension Selection
- Test Series Three: Influence of Track Width
- Test Series Four: Influence of Tire Choice
- Test Series Five: Influence of Fifth Wheel Vertical Slack

3.1 Vehicle Preparation and Setup

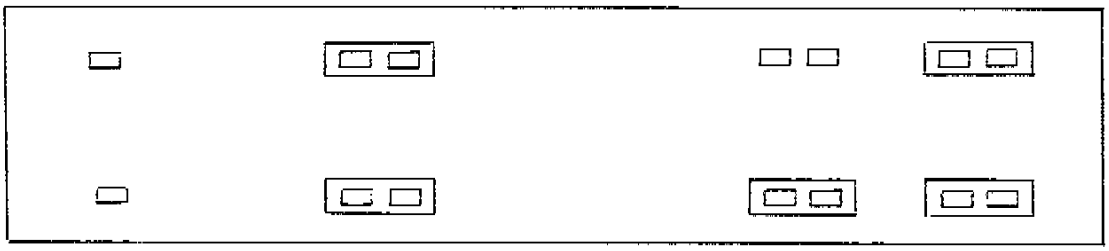
The vehicle basic configuration determined the way of positioning each vehicle and each weighing pad on the platform (figure 5); however, the last trailer axle was always located at the same place.

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 $\pm$ 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.

TRACTOR - SEMI-TRAILER 5 AXLES



TRACTOR - SEMI-TRAILER 7 AXLES



A, B, C - TRAIN DOUBLE

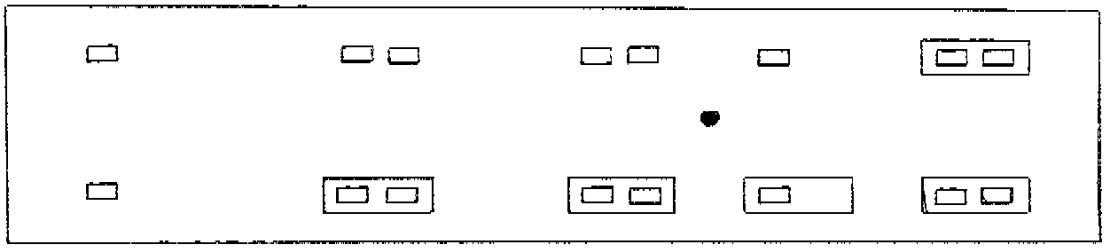


FIGURE 5: VEHICLES AND WEIGHING PADS POSITION

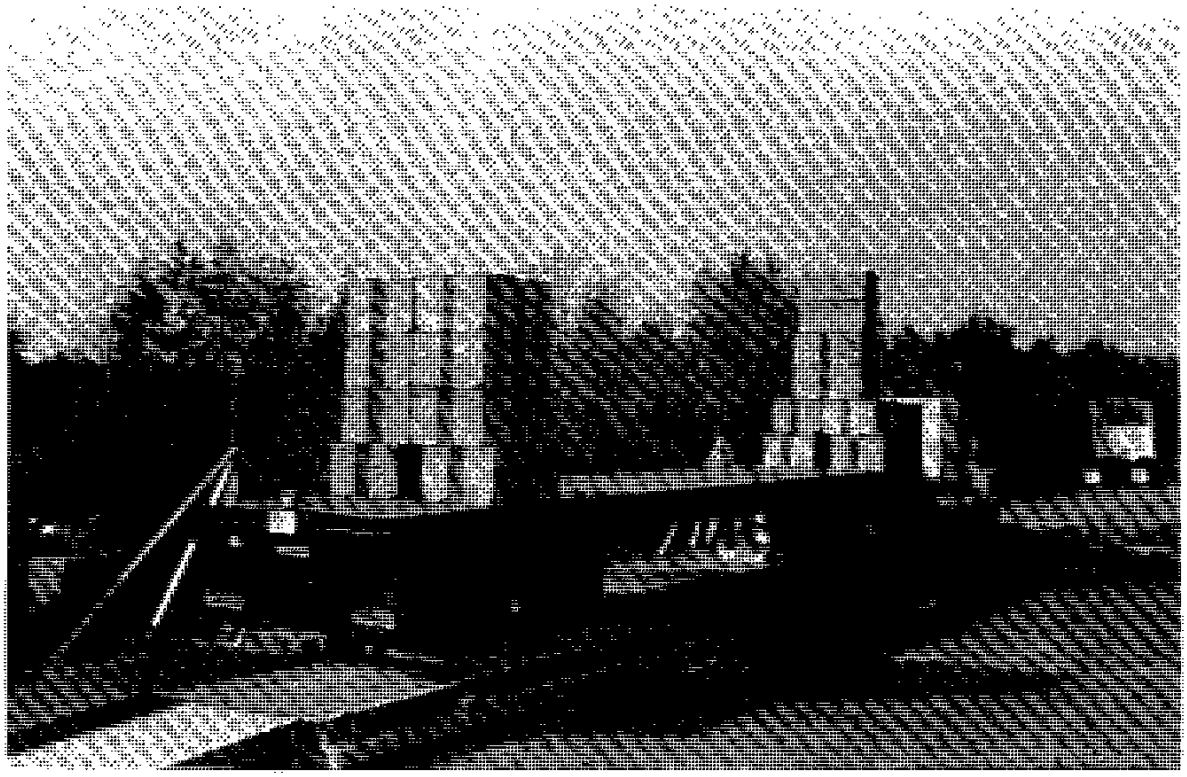


FIGURE 6

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

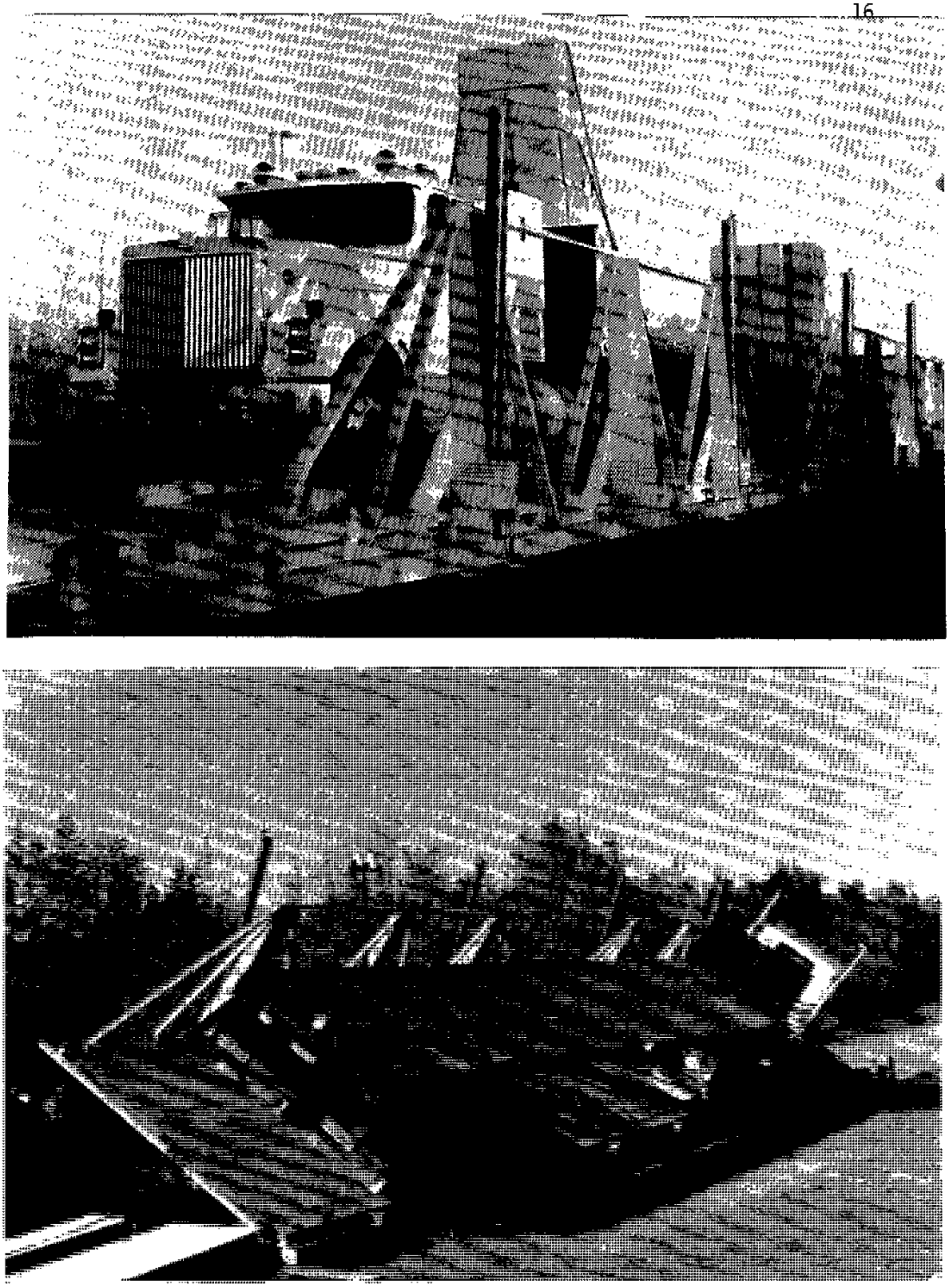


FIGURE 7

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 mesuring 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.

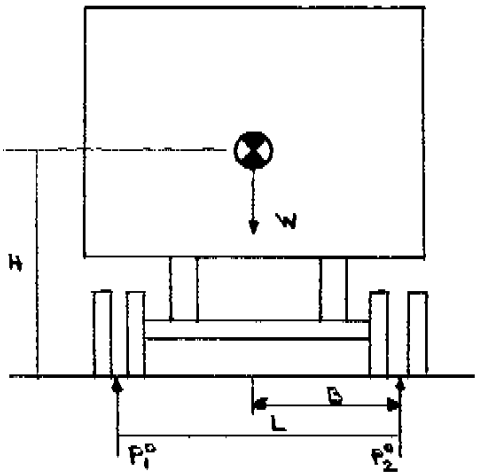
Data was recorded every four seconds during each tilt test. It was handled and computerized and printed on graphs and tables.

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.



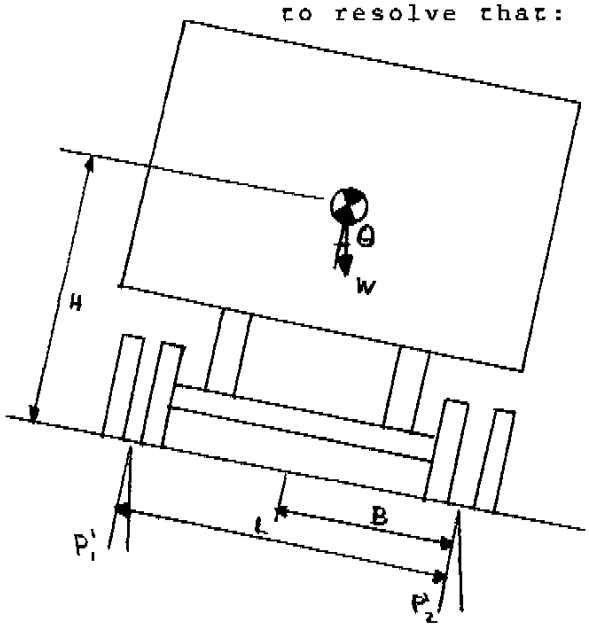
Then at equilibrium

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

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

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

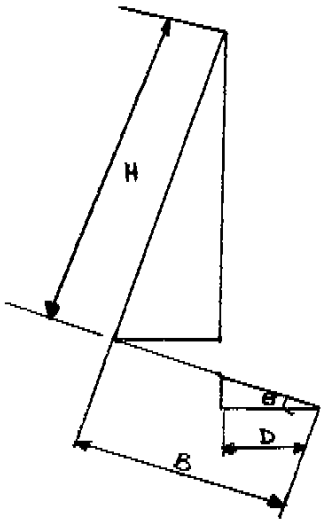
If this body is tilted with respect to the horizontal by an angle θ and assuming that the reactions to the ground remain at the same place, it is possible to resolve that:



$$\Sigma F_H = W \sin\theta - F_1 - F_2 = 0$$
$$\Sigma F_V = P_1' + P_2' - W \cos\theta = 0$$
$$\Sigma \Gamma_{P2}' = W \times D - P_1 \times L = 0$$

then $F_1 + F_2 = W \sin\theta$

$$D = \frac{P_1' \times L}{W} = \frac{P_1' \times L}{P_1^o + P_2^o}$$



$$\text{and } H \tan\theta + \frac{D}{\cos\theta} = B$$

$$H \sin\theta + D = B \cos\theta$$

$$H = B \cot\theta - D \operatorname{cosec}\theta$$

$$H = \frac{P_1^o \times L}{P_1^o + P_2^o \tan\theta} - \frac{P_1' \times L}{P_1^o + P_2^o \sin\theta}$$

$$H = \frac{L}{(P_1^o + P_2^o)\sin\theta}\left[P_1^o \cos\theta - P_1'\right]$$

if
- H : center of gravity height
- L : axle spread of the trailer
- W : total axle load
- P_1 : load applied to the high side reaction
- P_2 : load applied to the low side reaction
- P_1 : load applied to the high side reaction at $\theta = 0°$
- 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
- θ : tilt angle

This formula was chosen instead of the following:

$$H = -\frac{L}{W} P_1^o \tan\theta + \frac{1}{\cos\theta}\frac{\partial P_1}{\partial\theta}$$

$$H = -\frac{L}{W}\left[\frac{\partial P_1}{\partial\theta}\right]_{\theta = 0}$$

$$H = \frac{1}{W\cos\theta}\left[b\frac{\partial P_2}{\partial\theta} - (L - B)\frac{\partial P_1}{\partial\theta}\right]$$

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 θ. 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 θ 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
θ : 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 chasis (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:

	C OF G HEIGHT	TILT ANGLE AT WHEEL LIFT	LATERAL ACCELERATION
	CALCULATED	MEASURED	CALCULATED
Combination 1	1.52 m (60 in.)	28.5 degrees	0.54 g
Combination 2	2.13 m (84 in.)	19.3 degrees	0.35 g
% Change	+40%		- 35%

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, dimensionnaly similar tractors were obtained from International Harvester (Navistar) with the following tandem drive axle suspensions:

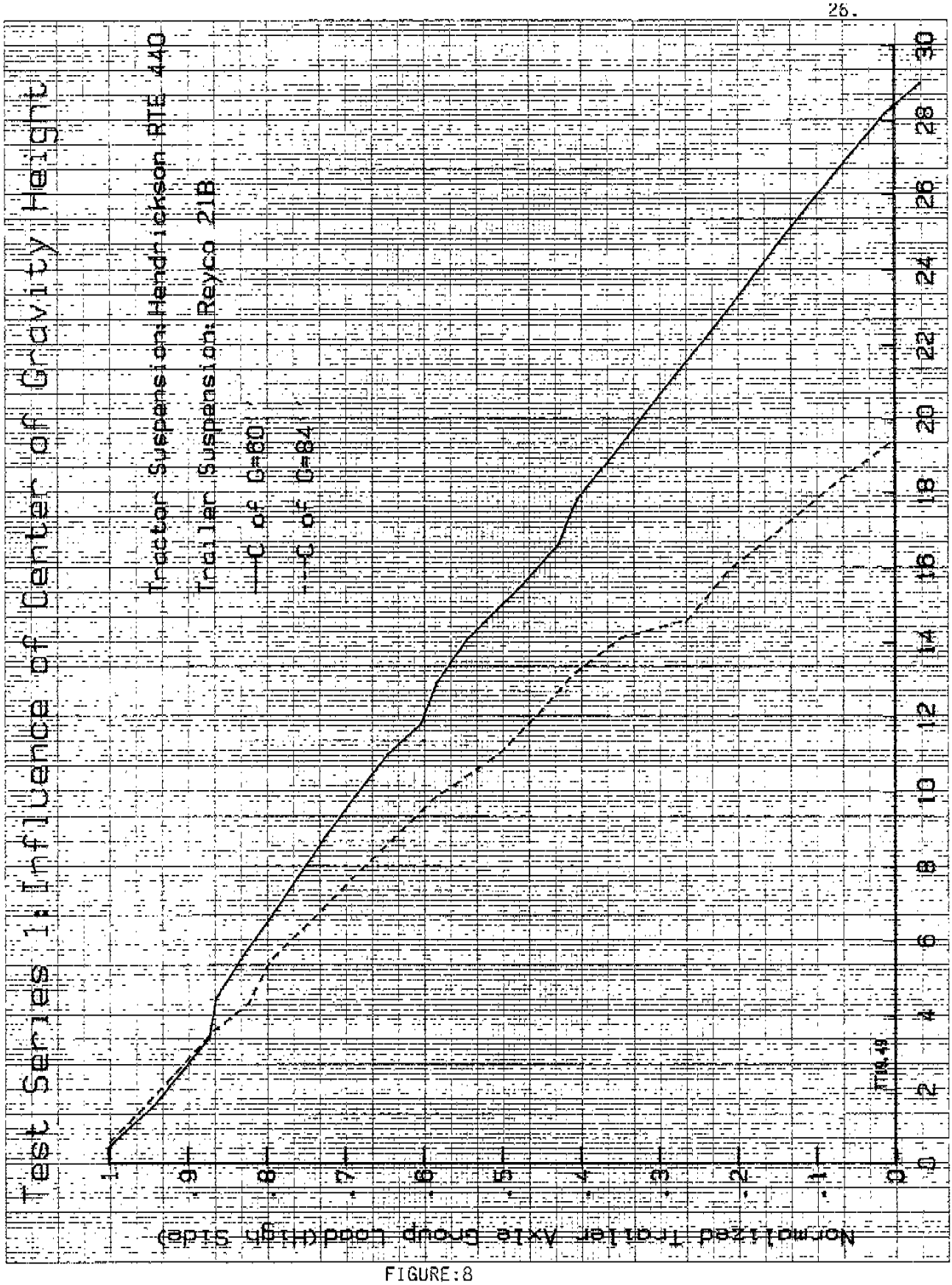


FIGURE:8

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 tamdem 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-semitrailer 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
STATIC ROLL THRESHOLD - TRACTOR SUSPENSION VARIATION

	TRAILER SUSPENSION		
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).

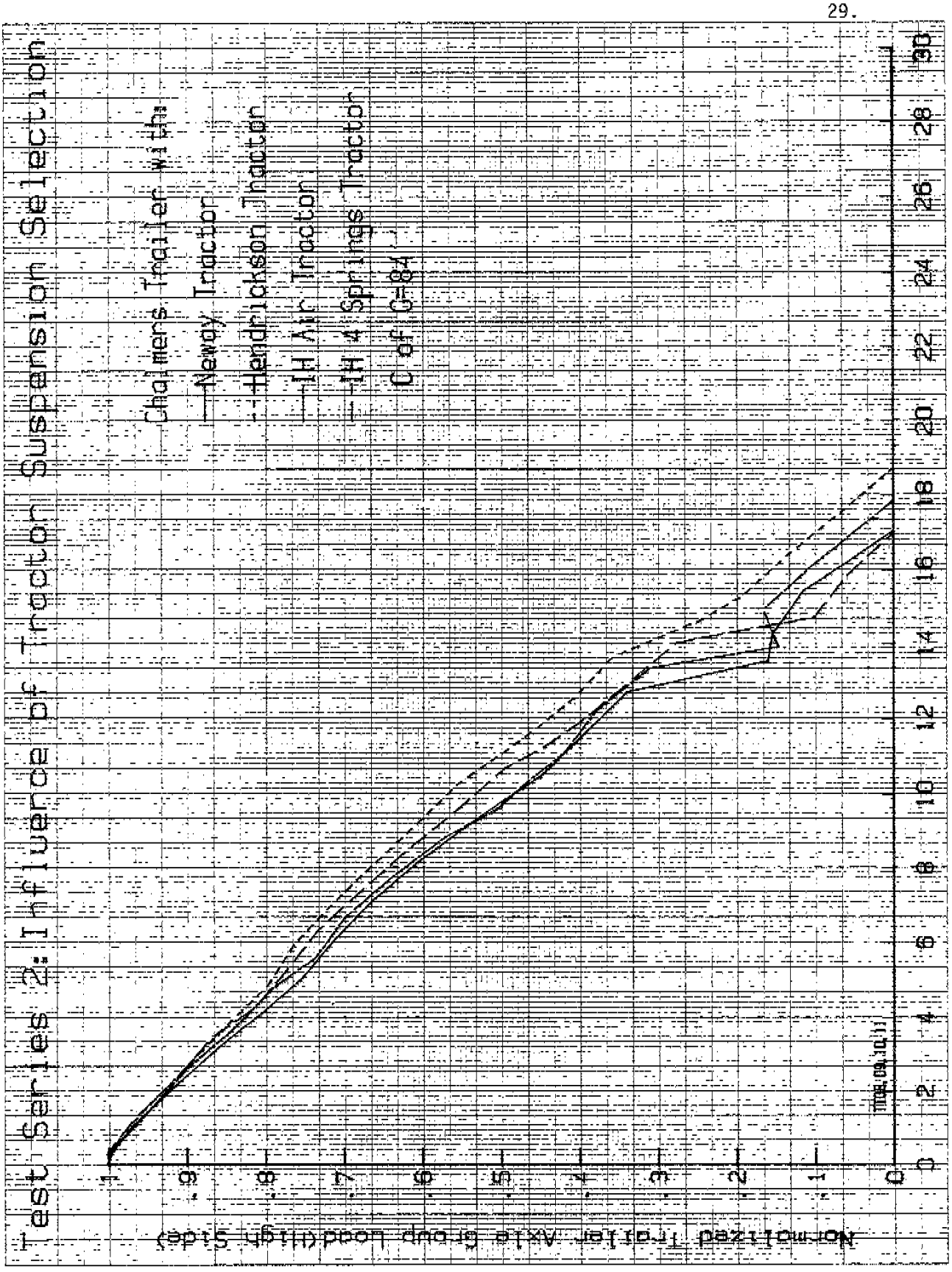


FIGURE:9

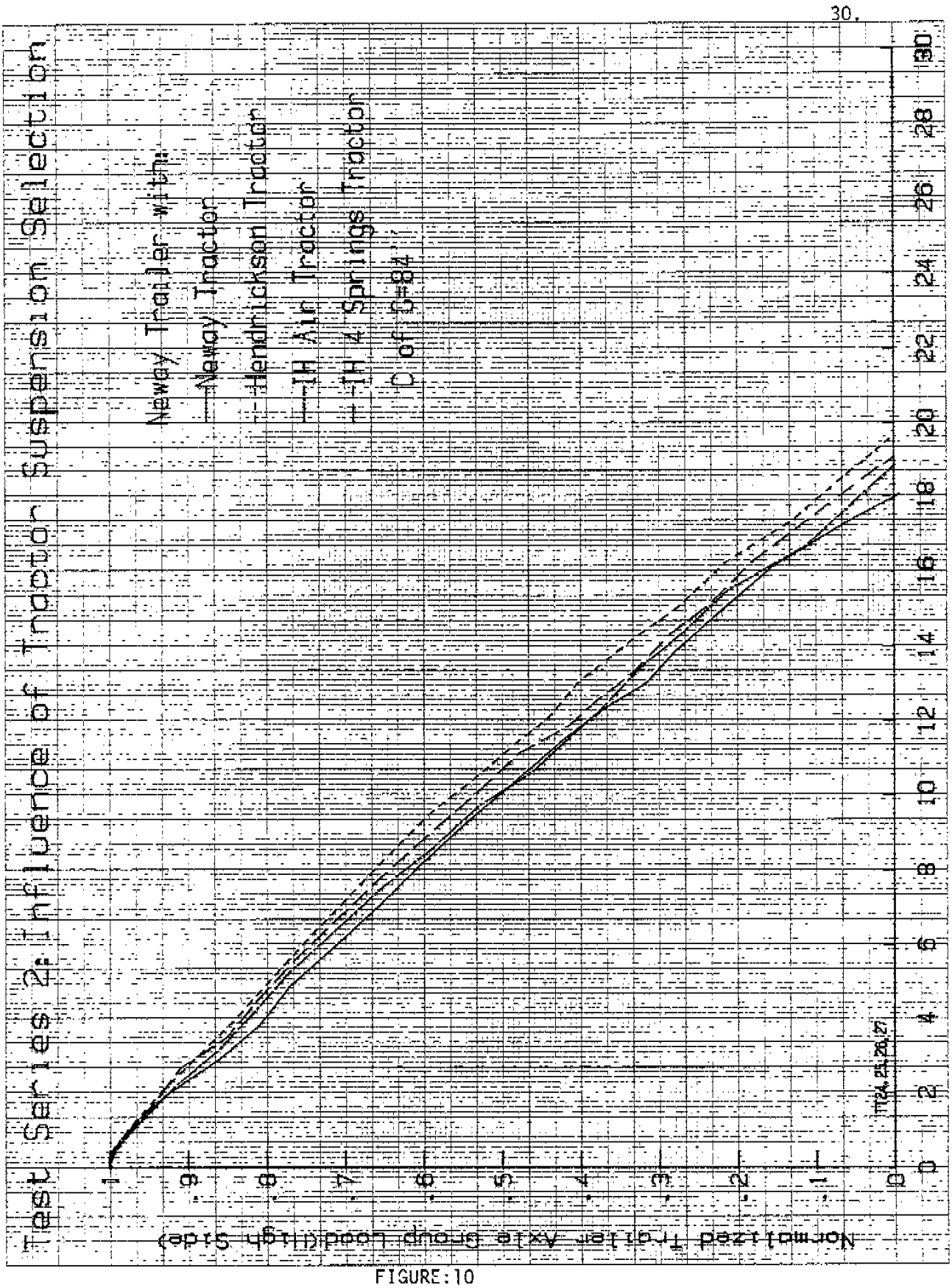

Test set-up influence of Tractor suspension selection
Neway Trailer with:
Neway Tractor
Hendrickson Tractor
1-IH Air Tractor 4 Springs traction
1-IH 4 Springs traction
Cof G 84"
Normalized Trailer Axle Group Loadlight Side)
Tilt Table Angle(D.)
30.
46 1512

FIGURE:10

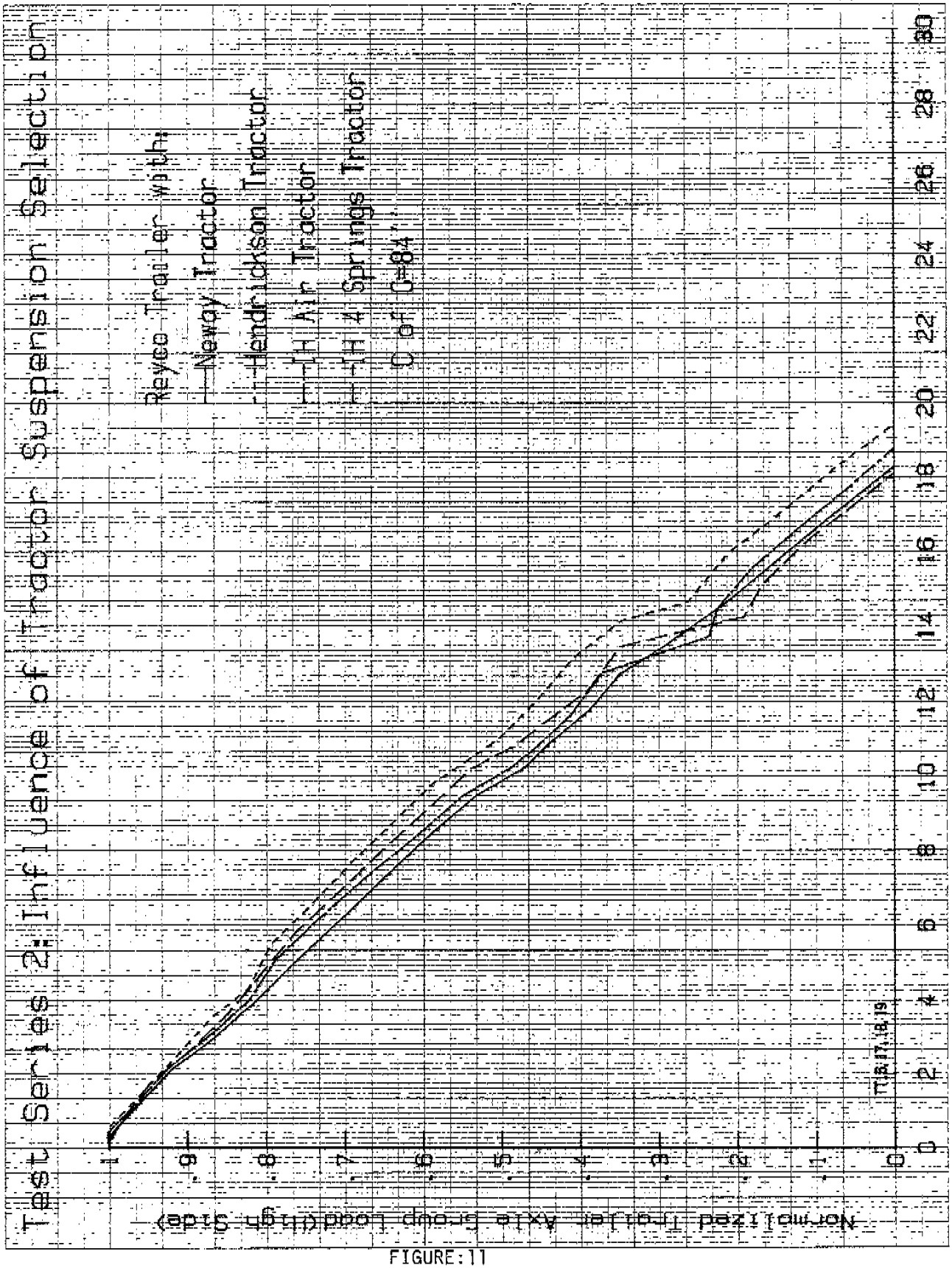


FIGURE:11

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 chasis 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 chasis 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:

TRACTOR SUSPENSION	TILT TABLE ANGLE	TRACTOR CHASIS (REAR) INCLINATION RELATIVE TO TILT TABLE
Hendrickson	8 degrees 16 degrees	0.8 degree 4.1 degrees
IH 4 Spring	8 degrees 16 degrees	1.4 degree 6.4 degrees
Neway Air	8 degrees 16 degrees	3.4 degrees 8.3 degrees
TH Air	8 degrees 16 degrees	3.8 degrees 8.5 degrees

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 chasis 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.

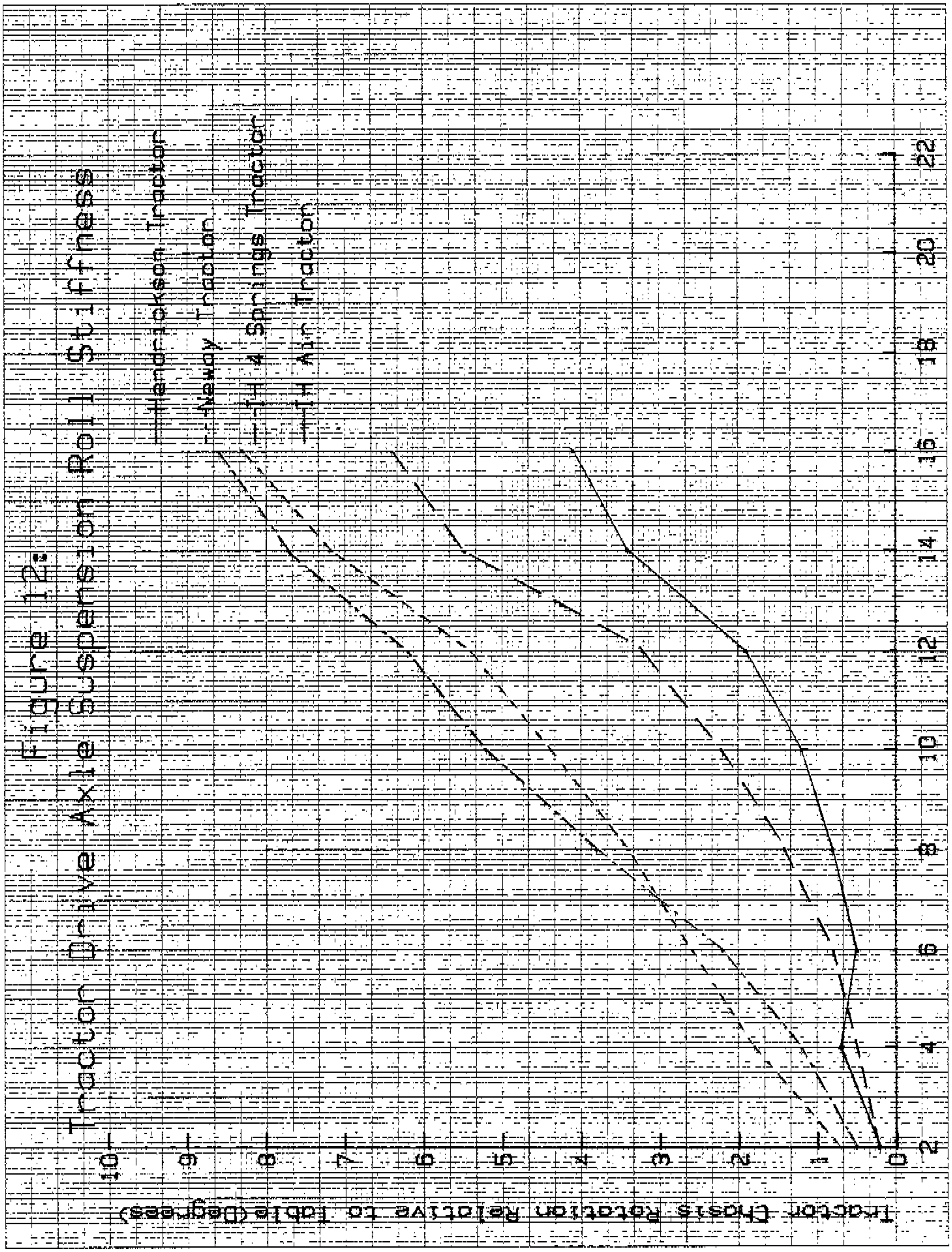


FIGURE:12

At a tilt table angle of 16 degrees, just prior to trailer wheel lift off, the walking beam suspension allowed 4.1 degrees of chasis 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
STATIC ROLL THRESHOLD - TRAILER SUSPENSION VARIATION

	TRACTOR DRIVE AXLE SUSPENSION			
TRAILER	HENDRICKSON	IH 4 SPRING	IH AIR	NEWAY
Chalmers	0.34 g	0.31 g	0.32 g	0.31 g
Reyco	0.35 g	0.33 g	0.34 g	0.33 g
Neway	0.36 g	0.35 g	0.34 g	0.32 g
% variation	5.8%	15.1%	4.8%	5.6%

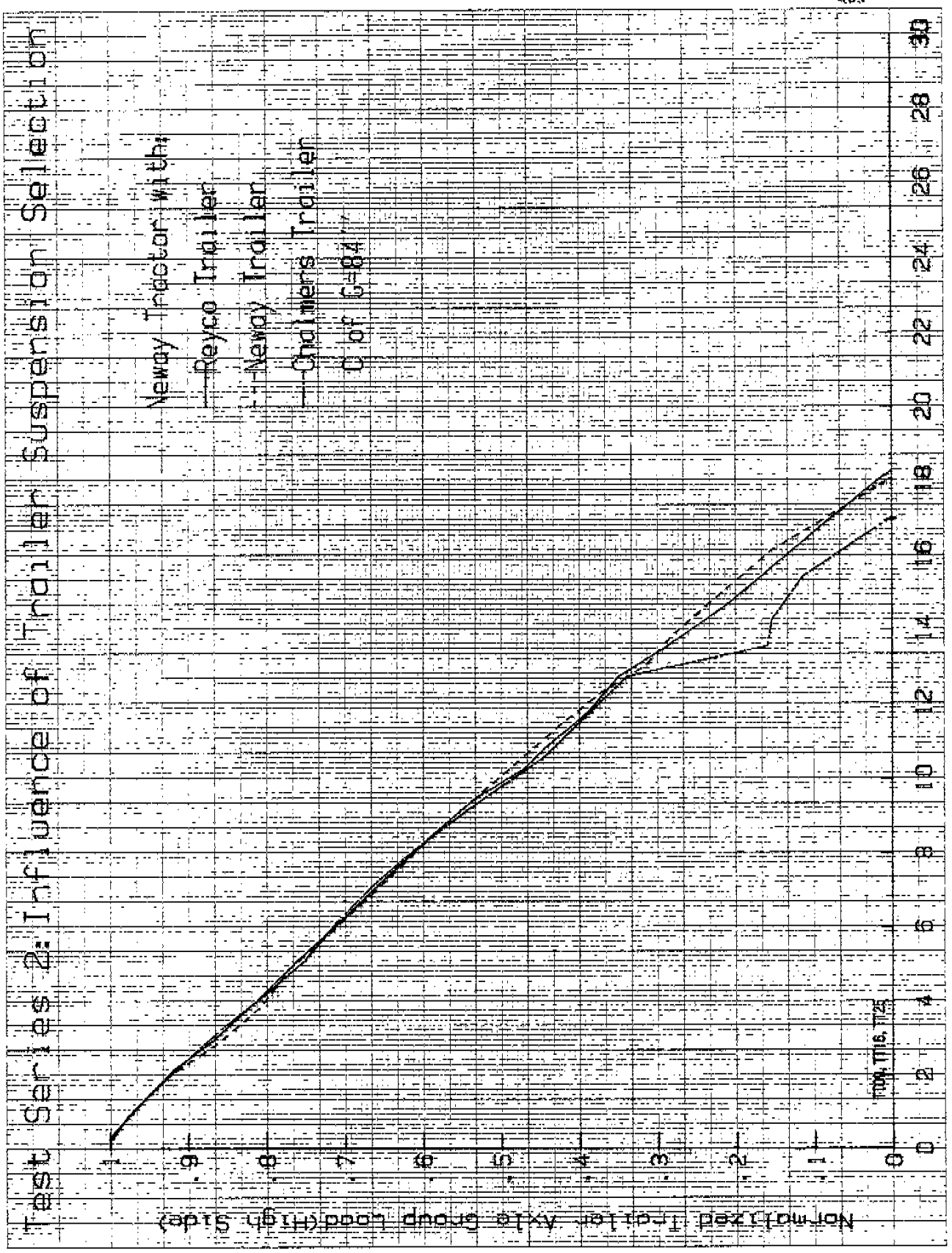

Trailer suspension Selection
Newly Tractor with
Reyco Trailer
Newly Trailer
Chalmers Trailer
C of G=84"
Normalized Trailer Axle Group Load(High Side)
Tilt Table Angle(D.)
mph, T16, T25

FIGURE:13

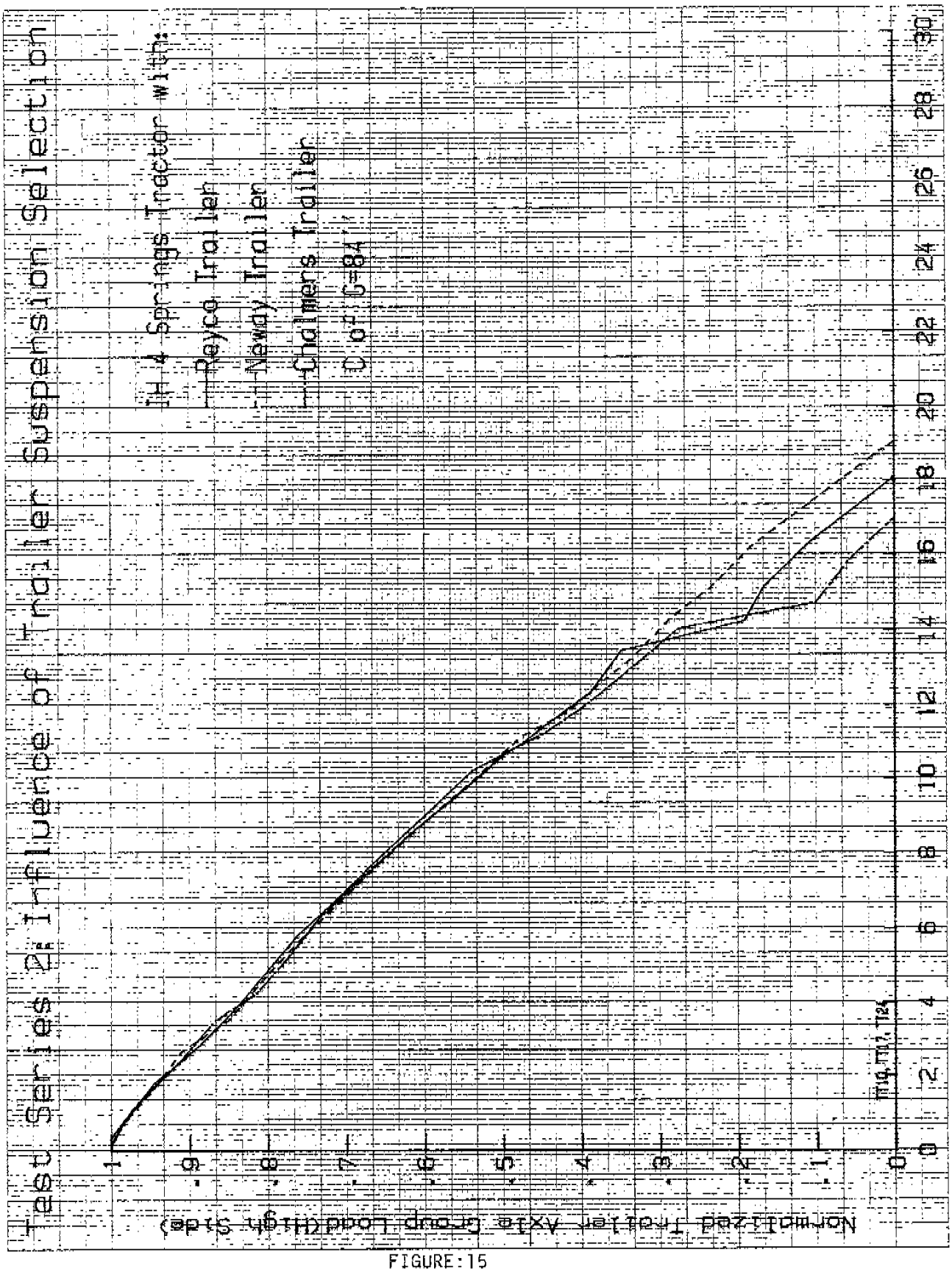


FIGURE:15

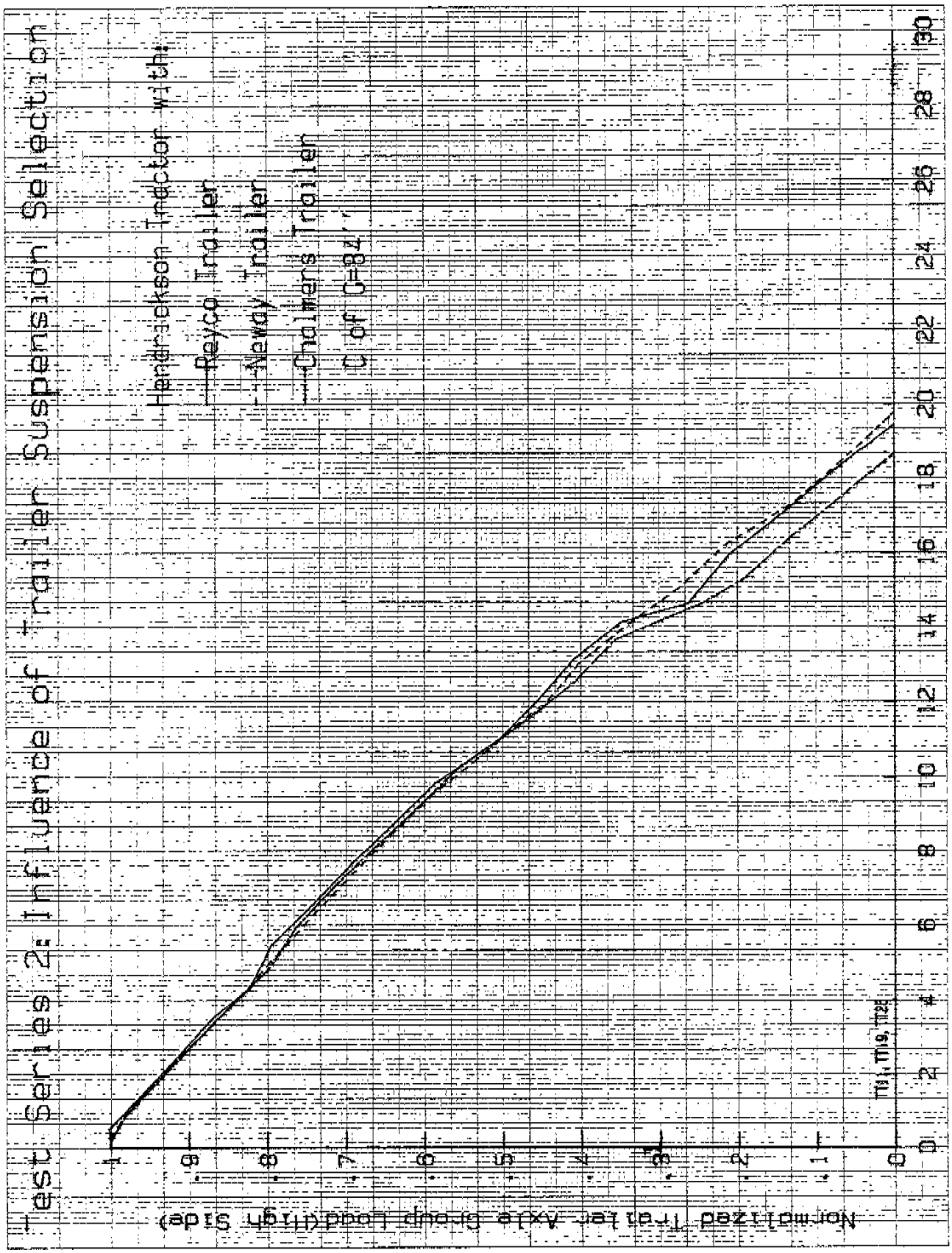


FIGURE:14

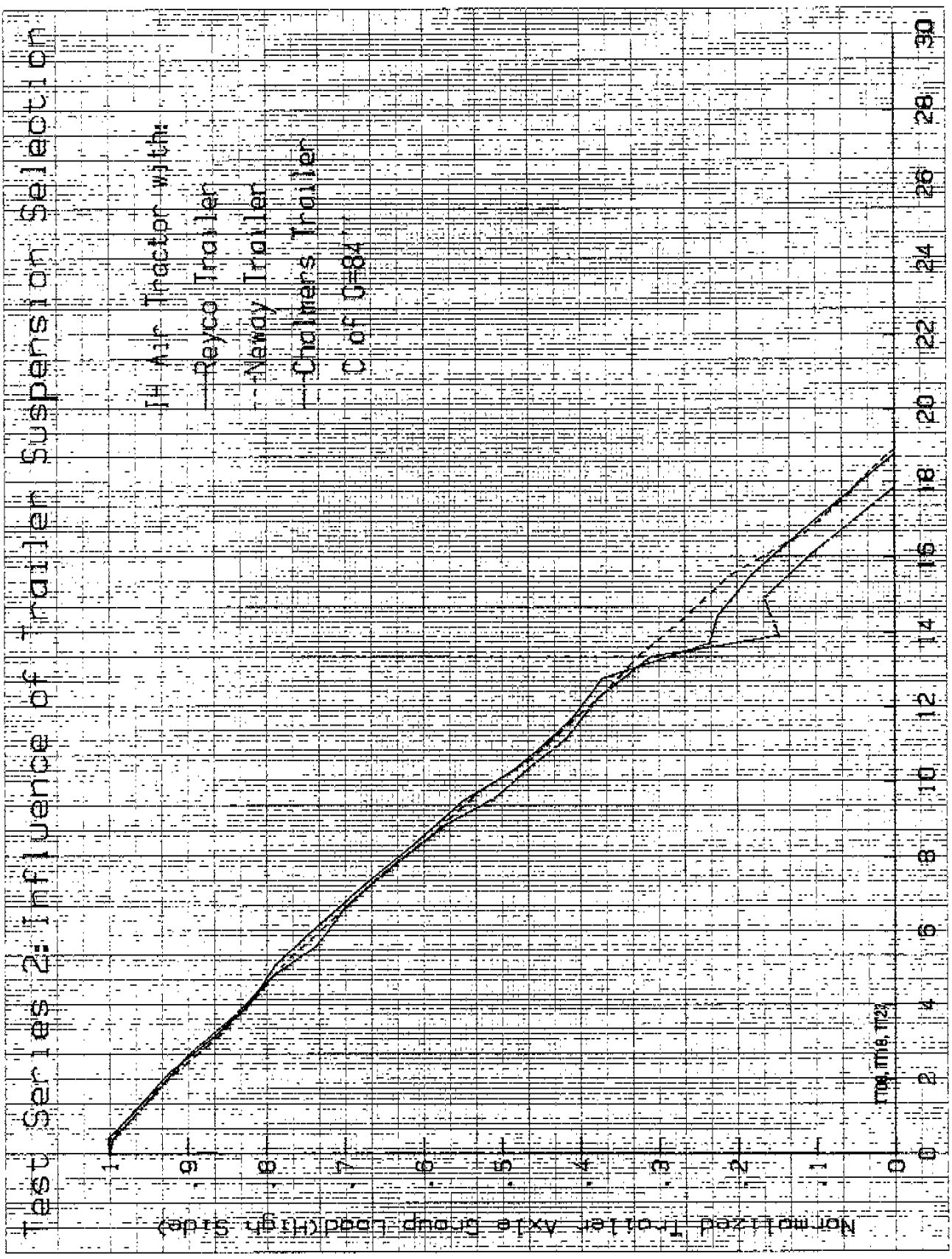


FIGURE:16

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:

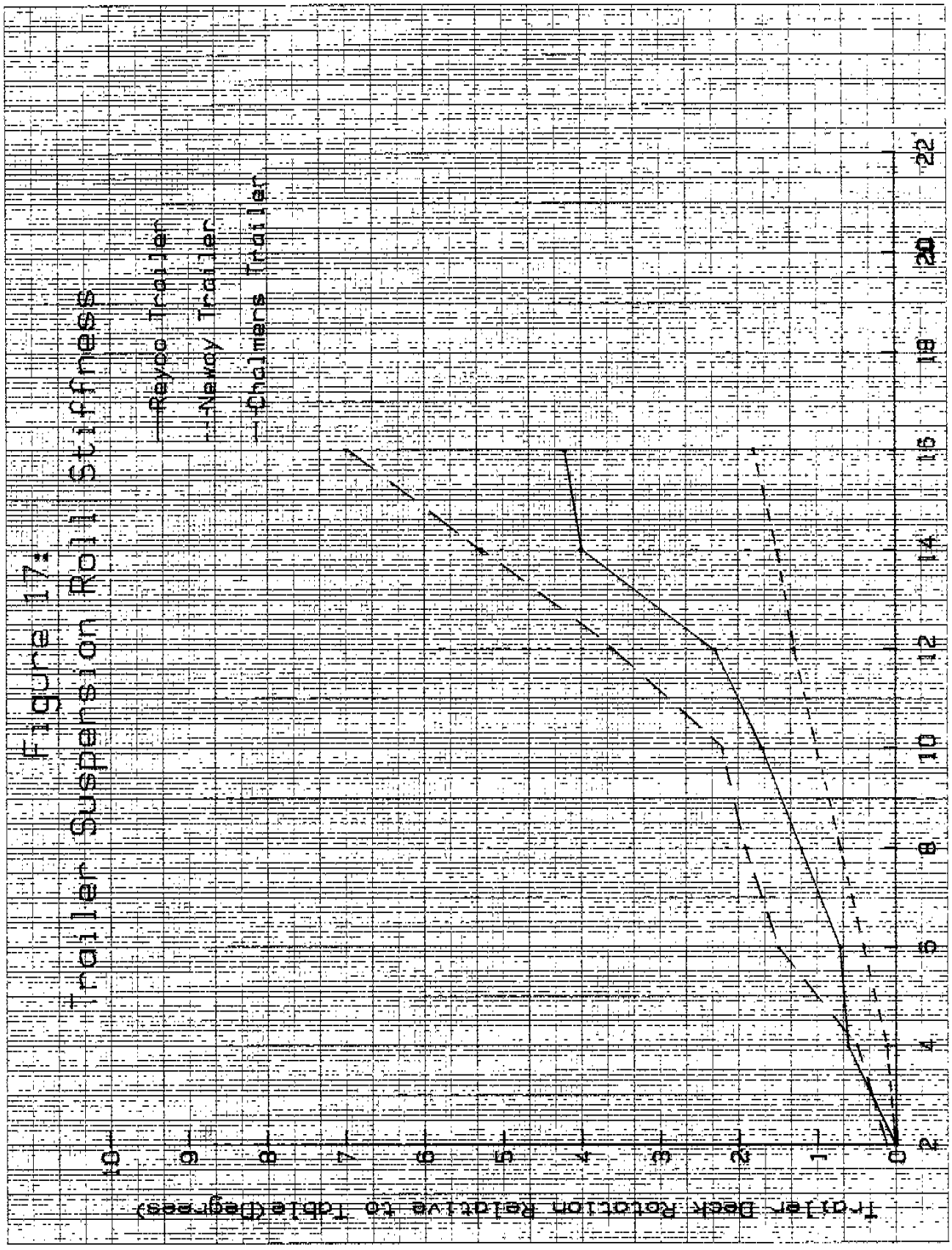

Trailer Deck Rotation Relative to Table(Degrees)
Tilt Table Angle(D)
Royce Trailer
Newby Trailer
Chalmans Trailer

FIGURE:17

TRACTOR SUSPENSION	TILT TABLE ANGLE	TRACTOR CHASIS (REAR) INCLINATION RELATIVE TO TILT TABLE
Chalmers	8 degrees 16 degrees	1.9 degree 7.0 degrees
Reyco	8 degrees 16 degrees	1.2 degree 4.2 degrees
Neway	8 degrees 16 degrees	0.7 degrees 1.8 degree

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 3
SUSPENSION VARIATIONS - Summary of Tilt Test Results

TRACTOR SUSPENSION	TRAILER SUSPENSION	TABLE ANGLE AT WHEEL LIFT	LATERAL ACCELERATION
		degrees	g
Hendrickson	Neway	19.7	0.36
Hendrickson	Reyco	19.5	0.35
IH 4 Spring	Neway	19.1	0.35
IH Air	Neway	18.8	0.34
IH Air	Reyco	18.8	0.34
Hendrickson	Chalmers	18.7	0.34
Neway	Reyco	18.3	0.33
IH 4 Spring	Reyco	18.1	0.33
Neway	Neway	18.0	0.32
IH Air	Chalmers	18.0	0.32
IH 4 Spring	Chalmers	17.1	0.31
Neway	Chalmers	17.1	0.31

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 21B 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:

TRAILER TRACK WIDTH (NOMINAL)	WIDTH ACROSS TIRES (ACTUAL)	TABLE ANGLE AT WHEEL LIFT	LATERAL ACCELERATION
96 in. (2.44 m)	92.5 in (2.35 m)	17.9 degrees	0.32 g
102 in. (2.59 m)	99,0 in (2.51 m)	19.1 degrees	0.35 g
% Change	+ 7.0%		+ 7.2%

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:

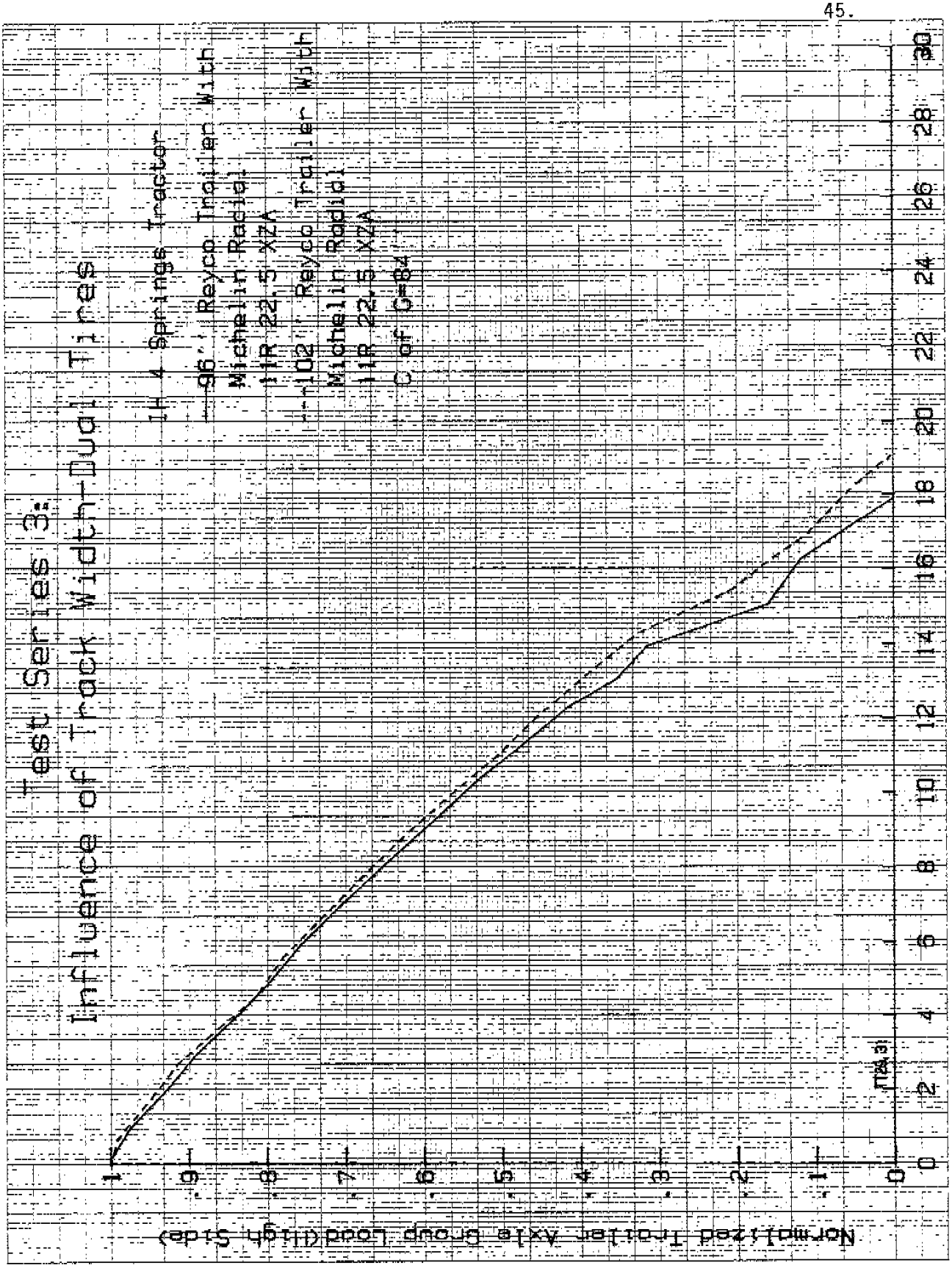

Test Series 3"
Influence of Track Width-Dual Tires
14 Springs Tractor
96" Reyco Trailer With
Michelin Radial
11R 22.5 XZA
11-102 Reyco Trailer Width
Michelin Radial
11R 22.5 XZA
C of G=84
Normalized Trailer Axle Group Load(High Side)
Tilt Table Angle(Deg)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
1
.9
.8
.7
.6
.5
.4
.3
.2
.1
0

FIGURE: 18

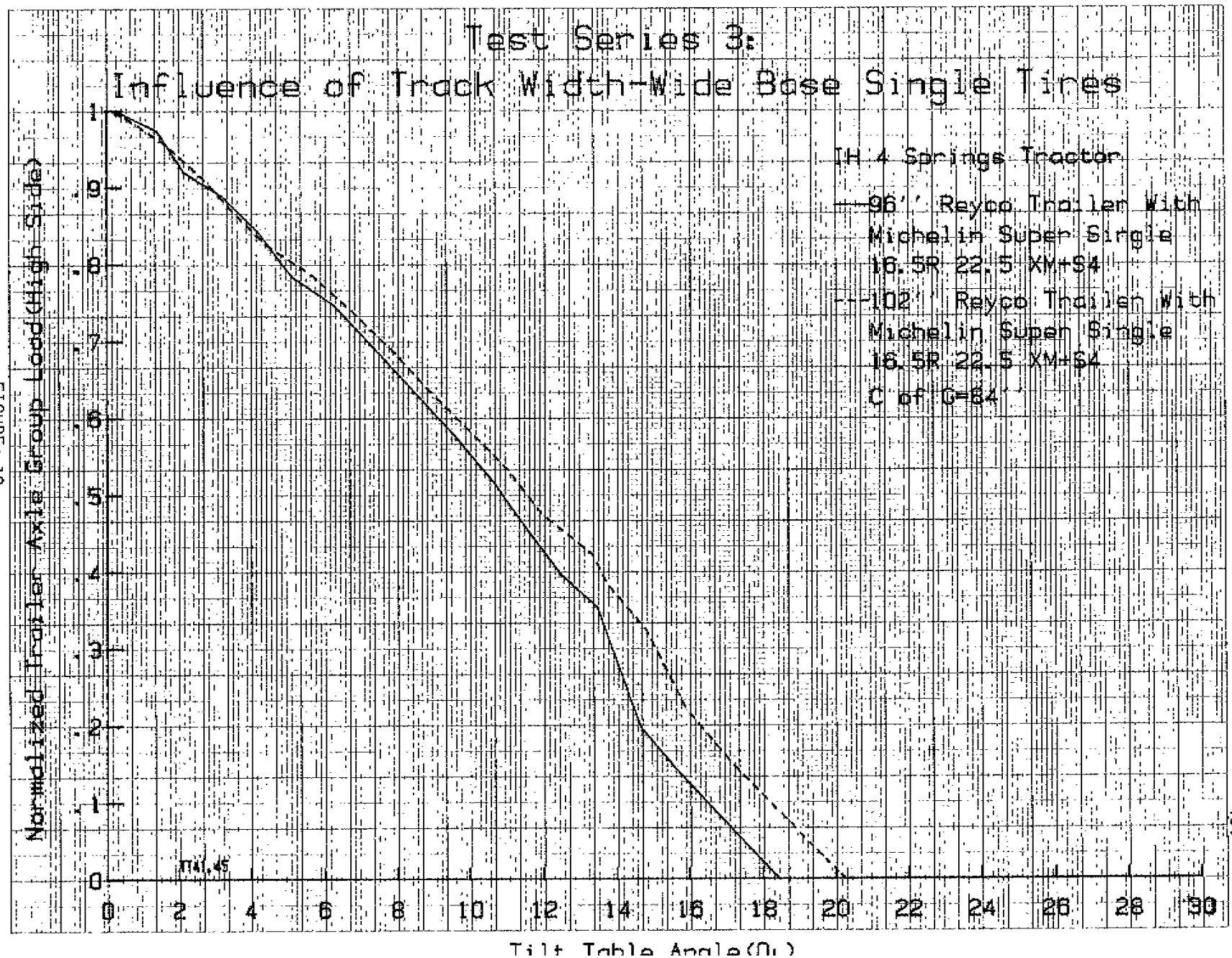

Test Series 3:
Influence of Track Width-Wide Base Single Tires
IH 4 Springs Tractor
96" Reyco Trailer With
Michelin Super Single
16.5R 22.5 XM+S4
102" Reyco Trailer With
Michelin Super Single
16.5R 22.5 XM+S4
C of G=84"
Normalized Trailer Axle Group Load(High Side)
Tilt Table Angle(θ)
0
1
2
3
4
5
6
7
8
9
10
12
14
16
18
20
22
24
26
28
30
Ø41.45

FIGURE: 19

TRAILER TRACK WIDTH (NOMINAL)	WIDTH ACROSS TIRES (ACTUAL)	TABLE ANGLE AT WHEEL LIFT	LATERAL ACCELERATION
96 in. (2.44 m)	92.5 in (2.35 m)	18.4 degrees	0.33 g
102 in. (2.59 m)	99.0 in (2.51 m)	20.3 degrees	0.37 g
% Change	+ 7.0%		+ 11.2%

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:

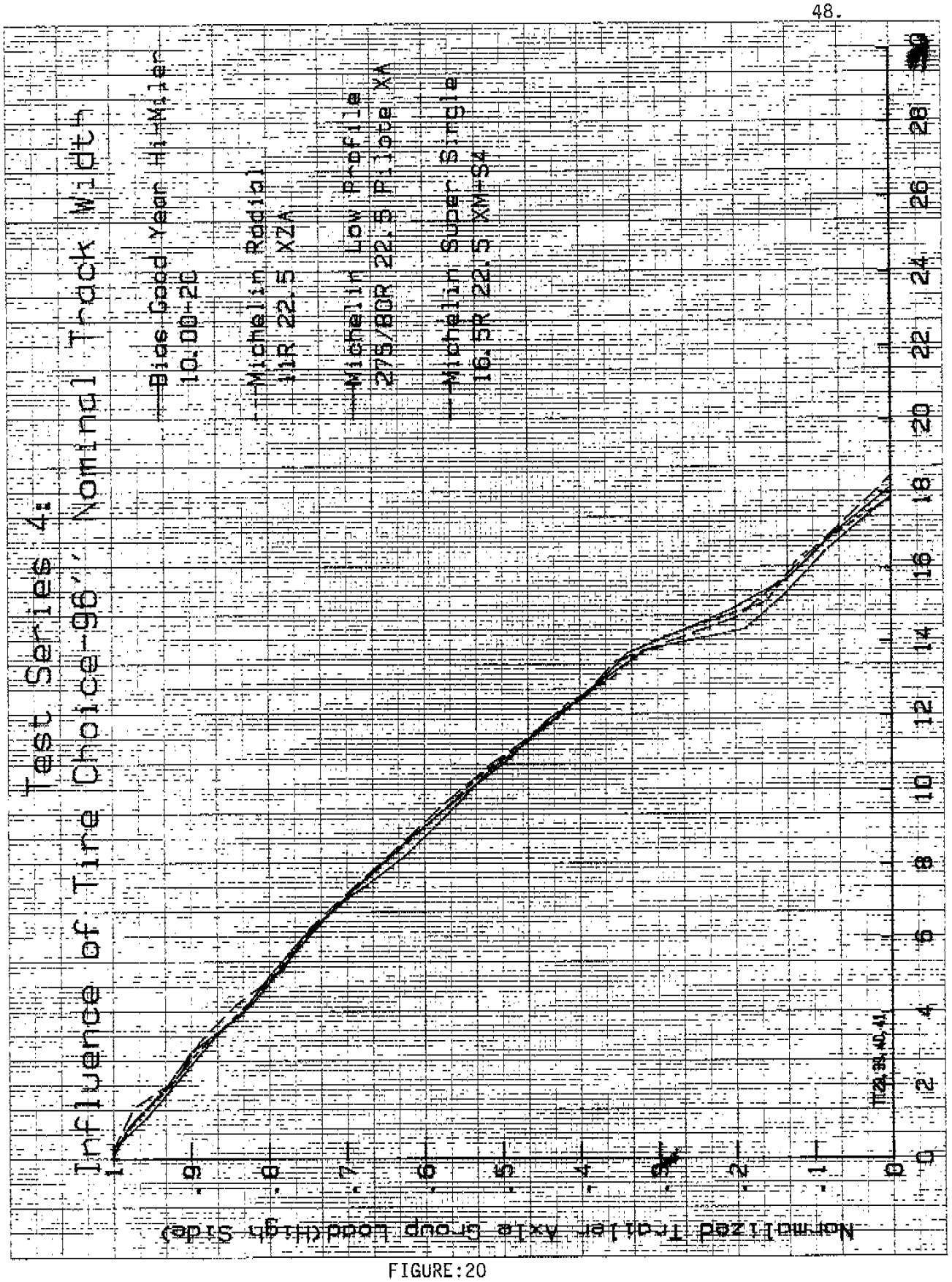


FIGURE:20

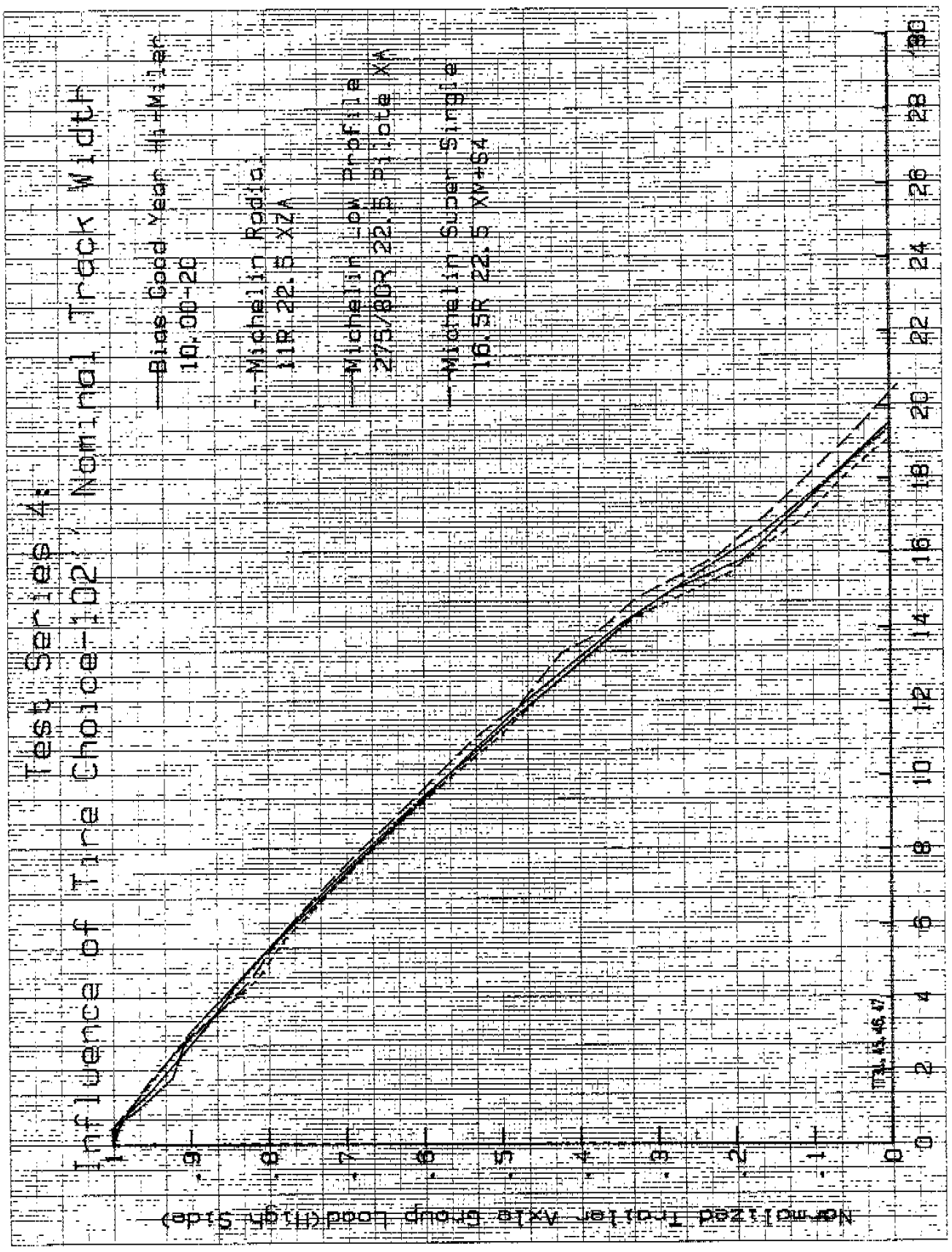


FIGURE:21

TIRE TYPE VARIATION: SUMMARY OF TILT TEST RESULTS

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

	TRAILER TIRE TYPE	TRAILER TIRE SIZE	WIDTH ACROSS TIRES	TABLE ANGLE AT WHELL LIFT	LATERAL ACCELERATION (calculated)
			inches	degrees	g
Case 1: 96 inch track					
Goodyear Hi-Miler	Bias Ply	10.00 - 20	95.0	18.1	0.33
Michelin XZA	Radial	11R 22.5	95.0	17.8	0.32
Michelin Pilote XA	Low Profile	275/80R 22.5	95.0	17.9	0.32
Michelin XM+S4	Super Single	16.5R 22.5	92.5	18.4	0.33
Case 2: 102 inch track					
Goodyear Hi-Miler	Bias Ply	10.00 - 20	100.0	19.5	0.35
Michelin XZA	Radial	11R 22.5	100.0	19.1	0.35
Michelin Pilote XA	Low Profile	275/80R 22.5	100.0	19.5	0.35
Michelin XM+4	Super Single	16.5R 22.5	97.5	20.3	0.37

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 ADJUSTEMENT

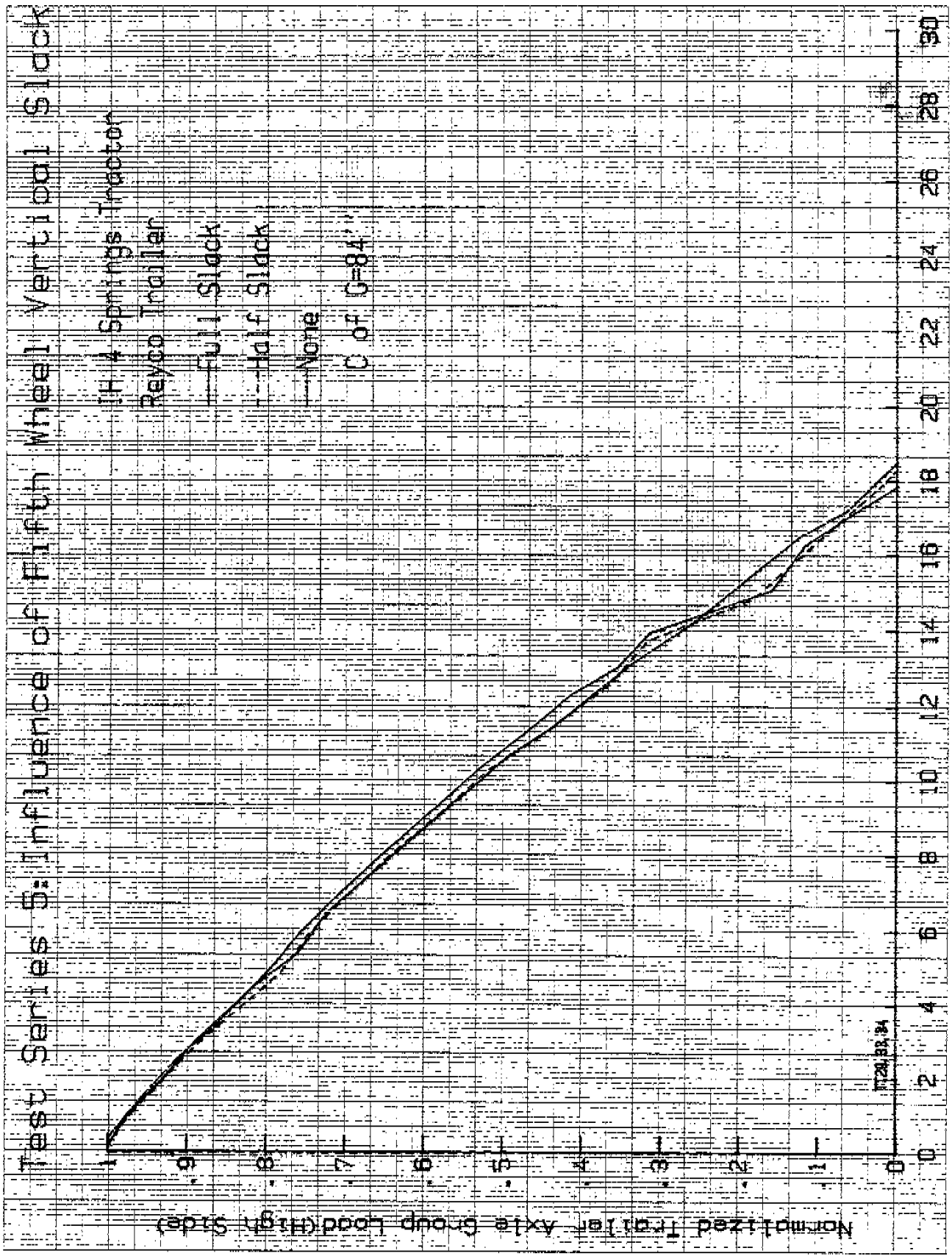

Normalized Trailer Axle Group Load(High Side)
TABLE ANGLE(DEG)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
1
2
3
4
5
6
7
8
9
Influence of Fifth Wheel Vertical Slack
1" & 4" Springs
Reyco Trailer
Full Slack
1/2 Slack
None
C of G=84"

FIGURE:23

Tractor Suspension: IH 4 Spring
Trailer Suspension: Reyco 21B
Fifth Wheel: Fontaine

	TABLE ANGLE AT WHEEL LIFT	LATERAL ACCELERATION	% CHANGE FROM NORMAL
	degrees	g	%
Normal Slack present	17.9	0.32	-
Half Slack Removed (¼ in.)	18.3	0.33	2%
All Slack Removed (½ in.)	18.5	0.34	4%

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 conventionnaly 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

1. Articulated Vehicle Stability - Phase II Tilt Tests and Computer Model - L. Mai, P. Sweatman - Australian Road Research Board (1984)

2. Summary of Tests of Baseline Vehicle Performance - J.R. Billing, Ontario Ministry of Transportation and Communications (1986)

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	8,02M
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	Hendrickson RTE 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
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

Description

TRACTOR TYPE	1975 Freightliner
TRAILER TYPE	Ram 13,71M Flat Bed
TRACTOR LENGTH	6,84M
TRAILER LENGTH	13,71M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 24.5 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Reyco 21B
AXLE SPREAD ON TRACTOR	3,47M 1,85M
AXLE SPREAD ON TRAILER	1,37M
TRACK WIDTH ON TRACTOR	2,43M
TRACK WIDTH ON TRAILER	2,43M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,32M
AMBIENT TEMPERATURE	10°C

1149

TEST SERIES TWO:

INFLUENCE OF SUSPENSION SELECTION

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
TRAILER LENGTH	14,78M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 22.5 X2A
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 X4A
SUSPENSION TYPE ON TRACTOR	IH Air
SUSPENSION TYPE ON TRAILER	Chalmers 700
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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,21M
AMBIENT TEMPERATURE	5°c

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
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 ARD 244
SUSPENSION TYPE ON TRAILER	Chalmers 700
AXLE SPREAD ON TRACTOR	4,85M 1,55M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,40M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,25M
AMBIENT TEMPERATURE	5°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 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 1,32M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	0°c

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	8,02M
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	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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,21M
AMBIENT TEMPERATURE	5°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 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	1H 4 Springs
SUSPENSION TYPE ON TRAILER	Neway AR95-17
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°C

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,79M
TRAILER LENGTH	14,78M
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 ARD 244
SUSPENSION TYPE ON TRAILER	Neway AR95-17
AXLE SPREAD ON TRACTOR	4,85M 1,55M
AXLE SPREAD ON TRAILER	1,89M
TRACK WIDTH ON TRACTOR	2,40M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,25M
AMBIENT TEMPERATURE	10°c

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	8,02M
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	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Neway AR95-17
AXLE SPREAD ON TRACTOR	5,12M 1,35M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,36M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
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 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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,24M
AMBIENT TEMPERATURE	16'c

DESCRIPTION

TRACTOR TYPE	Inter F-9370
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 ARD 244
SUSPENSION TYPE ON TRAILER	Keyco 21B
AXLE SPREAD ON TRACTOR	4.85M 1.55M
AXLE SPREAD ON TRAILER	1.69M
TRACK WIDTH ON TRACTOR	2.40M
TRACK WIDTH ON TRAILER	2.35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1.24M
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 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
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	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
WEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
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 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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	8,02M
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	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Reyco 21B
AXLE SPREAD ON TRACTOR	5,12M 1,35M
AXLE SPREAD ON TRAILER	1,70M
TRACK WIDTH ON TRACTOR	2,36M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	2°c

TEST SERIES THREE:

INFLUENCE OF TRAILER AXLE WIDTH

DESCRIPTION

TRACTOR TYPE	Inter F-9670
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 16.5R 22.5 XM+S4
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	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	10°c

DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Req
TRACTOR LENGTH	7,72M
TRAILER LENGTH	14,78M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER	Michelin Single 16.5R 22.5 XM+S4
SUSPENSION TYPE ON TRACTOR	IH 4 Springs
SUSPENSION TYPE ON TRAILER	Reyco 218
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
HEIGTH 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 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	1H 4 Springs
SUSPENSION TYPE ON TRAILER	Revco 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
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	10°c

Description

TRACTOR TYPE	Inter F-9670
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	Reyco 21S
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
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	16'c

TEST SERIES FOUR:

INFLUENCE OF TIRE SELECTION

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	Reyco 216
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
HEIGTH 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 XZA
TIRE TYPE ON TRAILER	Michelin 275/80R 22.5 Pilote XA
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	2,34M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	14°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 XZA
TIRE TYPE ON TRAILER	Good Year Hi-Miler 10.00-20
SUSPENSION TYPE ON TRACTOR	IH 4 Springs
SUSPENSION TYPE ON TRAILER	Revco 21B
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,57M
TRACK WIDTH ON TRAILER	2,34M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,21M
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 XZA
TIRE TYPE ON TRAILER	Michelin Single 16.5R 22.5 XM+S4
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	100 Psi
HEIGTH 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 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
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
HEIGTH 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 XZA
TIRE TYPE ON TRAILER	Michelin Single 16.5R 22.5 XM+S4
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	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,51M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH 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 XZA
TIRE TYPE ON TRAILER	Michelin 275/80R 22.5 Pilote XA
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	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,51M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	8°c

Description

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,73M Flat Bed
TRACTOR LENGTH	7,72M
TRAILER LENGTH	14,76M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 22.5 XZA
TIRE TYPE ON TRAILER	Good Year Super Hi-Miler 10.00-20
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	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,51M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	8°c

TEST SERIES FIVE:

INFLUENCE OF FIFTH WHEEL VERTICAL SLACK

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	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	12°c

Description

TRACTOR TYPE	Inter F-4370
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	Reyco 21B
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
HEIGTH OF THE FIFTH WHEEL	1,17M
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 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	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
HEIGTH OF THE FIFTH WHEEL	1,17M
AMBIENT TEMPERATURE	8°c

APPENDIX 2

CALIBRATION OF INSTRUMENTATION

PAD LOAD CELLS

SPECIFICATIONS AND CALIBRATION

E. Farr
APPROVALS

SENSORTRONICS
858 EAST EDNA PLACE • COVINA, CA 91723

65058-10K/200K
PAGE 1 OF 1 REV

TECHNICAL SPECIFICATION

1.0 GENERAL DESCRIPTION:

1.1 Customer: Standard Product

1.2 Customer Part Number:

1.3 Dim. Outline Dwg: 65058-10K/200K

2.0 PERFORMANCE SPECIFICATION:

2.1 Rated Capacity: 10K/200K Pounds

2.2 Rated Overload: 150 %

2.3 Rated Excitation: 15 VDC Volts

2.4 Bridge Resistance

Output: 700 ± 7 Ohms Input: 700 ± 7 Ohms

2.5 Full Scale Output: 3.0 MV/V Tolerance: ± 0.25 %FS

2.6 Zero Balance: ± 1 %FS

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

2.8 Current Load: N/A

Tolerance: N/A

Platform Size: N/A

Load: N/A

2.9 Linearity: .03 % Reading

2.10 Hysteresis: .02 %FS

2.11 Insulation Resistance: 5000 Megohms @ 50 VDC

2.12 Compensated Temperature Range: 0-150 F

2.13 Thermal Zero Shift: .0015 %FS °F

2.14 Thermal Sensitivity Shift: .0008 % °F

2.15 Identification: Standard

CERTIFIED
FEB 22 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100409

FULL SCALE OUTPUT 3.004 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100407

FULL SCALE OUTPUT 3.005 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100410

FULL SCALE OUTPUT 2999 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100408

FULL SCALE OUTPUT 2998 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

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

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100399

FULL SCALE OUTPUT 3.000 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

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

SENSORTRONICS

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

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100417

FULL SCALE OUTPUT 3.000 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100415

FULL SCALE OUTPUT 3.001 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100418

FULL SCALE OUTPUT 3.001 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100416

FULL SCALE OUTPUT 2.998 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

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

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 60058-25K

CAPACITY 25K S/N 100403

FULL SCALE OUTPUT 2.999 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 60058-25K

CAPACITY 25K S/N 100406

FULL SCALE OUTPUT 3.006 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 60058-25K

CAPACITY 25K S/N 100404

FULL SCALE OUTPUT 3.003 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100413

FULL SCALE OUTPUT 2.994 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100411

FULL SCALE OUTPUT 2.999 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100414

FULL SCALE OUTPUT 3.002 MV/V

DATE SHIPPED MAY 2 3 1985

SENSORTRONICS

838 EAST EDNA PLACE COVINA, CA 91723

CALIBRATION CERTIFICATE
LOAD CELL

MODEL 65058-25K

CAPACITY 25K S/N 100412

FULL SCALE OUTPUT 3.000 MV/V

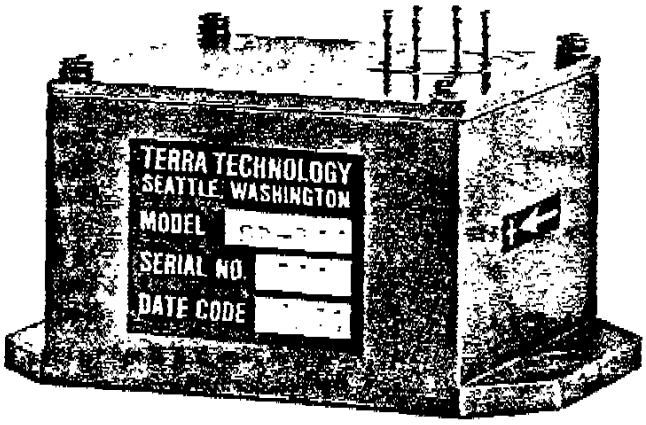
DATE SHIPPED MAY 2 3 1985

TABLE TILT SENSOR: Terra SA-111

INCLINOMETERS: PENNYS AND GILES CETS/60

SERVO ACCELEROMETER

TERRA — FLEX® MODELS SA-102 & SA-111



U.S. Patent No. 4,088,027

- RUGGED, FLUID DAMPED FLEXURE SUSPENSION
- LOW THERMAL COEFFICIENT
- FIELD RANGEABLE
- USER CONNECTABLE 1g BIAS
- EXCELLENT BIAS STABILITY
- TELEMETRY MODELS AVAILABLE
- CHOICE OF SENSITIVE AXIS
- BROAD DYNAMIC RANGE
- LOW OUTPUT IMPEDANCE
- WIDE FREQUENCY RESPONSE

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:[1]	±0.1 to 10g
FULL SCALE OUTPUT:[2]	±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)

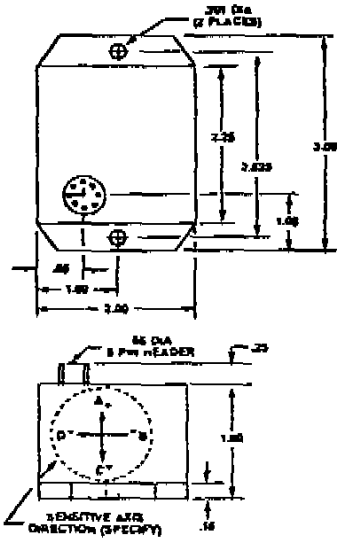
	SA-102	SA-111
BIAS, HORIZONTAL:	0.010g	0.005g
BIAS, VERTICAL:	0.020g	0.010g
HORIZ. BIAS TEMP. COEF:	50μg/°F max.	20μg/°F max.
SCALE FACTOR TEMP. COEF:	100 ppm/°F max.	50 ppm/°F max.

NOTES

(1) UNITS ARE SUPPLIED WITH 0.1g 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 0-5 VDC OUTPUT.

OUTLINE DIMENSIONS (inches)



CONNECTIONS

PIN	DUAL SUPPLY	SINGLE SUPPLY
1	+ Power	+ Power
2	− Power	Power Grd.
3	Pwr. & Sig. Grd.	Signal 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

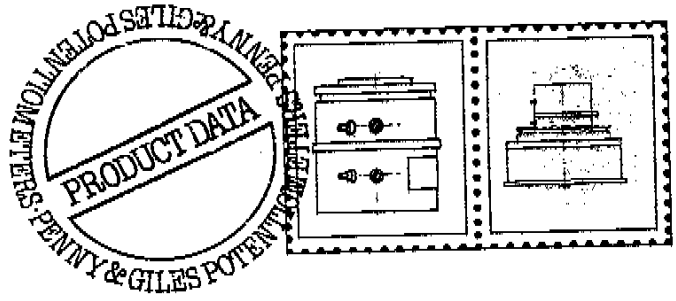
ORDERING INFORMATION: Specify model number, range, sensitive direction, and performance options desired. For example, SA-102-1-B-F is a Model SA-102, ±1g, with case alignment of 1/4° and telemetry output. Full scale output is ±5 VDC unless otherwise specified on the order (except for telemetry versions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

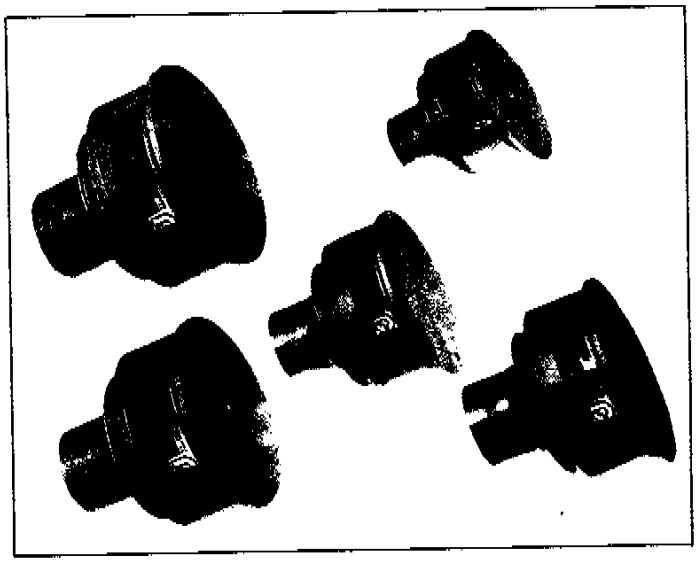
PRINTED IN USA



Penny & Giles
Potentiometers Limited

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.

Tilt Sensors
Variable Transformer Models
LOW COST

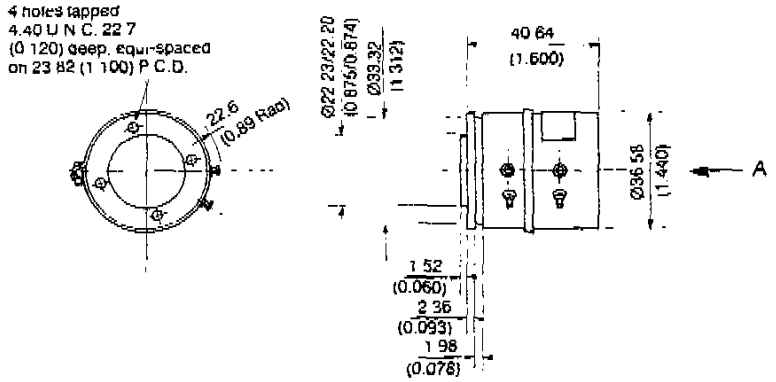
Performance specification

Model number	CETS/200	CETS/100	CETS/60	CETS/30	CETS/20	CETS/4
Tilt measurement range	200 degrees	100 degrees	60 degrees	30 degrees	20 degrees	4 degrees
Output sensitivity per degree into 10kΩ load ±0 2%	45mV	90mV	140mV	240mV	340mV	470mV
Residual voltage – maximum at 0° arc	50mV	500mV	1.0V	1.0V	1 0V	1.0V
Linearity – deviation from best straight line	±0.5%	±0 5%	±0.5%	±0.5%	±0 5%	±0.5%
Mechanical angle	360°					
Input voltage	10 volts d.c. from a source impedance of less than 1 ohm					
Output	10V d.c. into 10kΩ load					
Resolution	infinite					
Hysteresis – maximum	30 minutes of arc					
Temperature range – operational	−20° to +60°C (non derangement −40°C to 100°C)					
Mean temperature coefficient	+10° to +40°C ±0.80mV per °C −20° to +60°C ±2.00mV per °C					
Output ripple (1.2k Hz)	0.05% FS +0.4% output					
Input current – nominal	50mA at 10.000V d.c.					
Weight – maximum	100 gm					

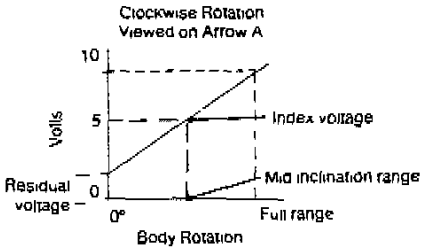
The specification data given above is true at 10 000V d.c. input with a 10kΩ load impedance on output.

Dimensions

all dimensions in millimetres (inches)



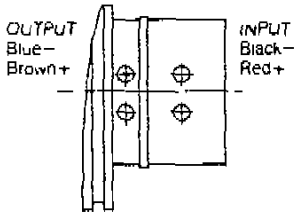
Output characteristic



Electrical connections – all models

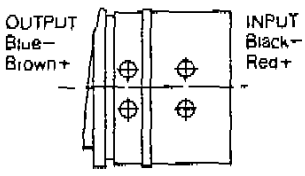
high sensitivity model – 3910

NORMAL DUTY SENSOR



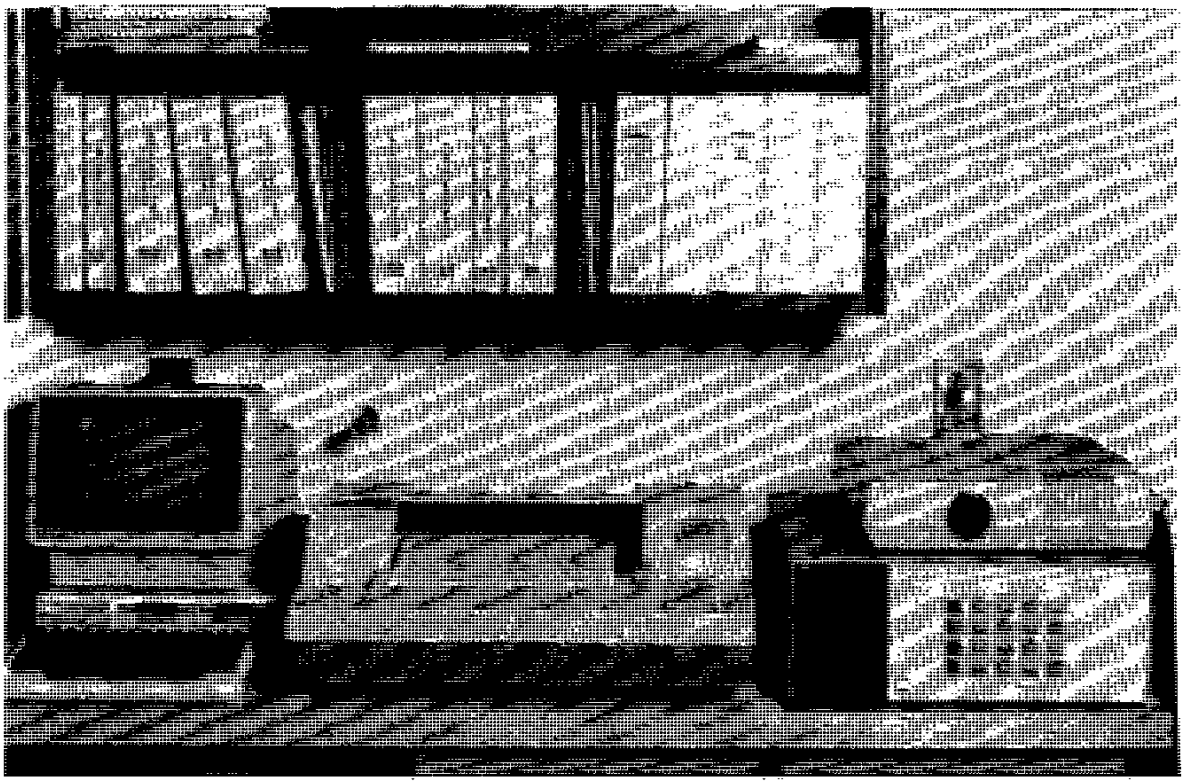
COMPLETELY SEALED SENSOR

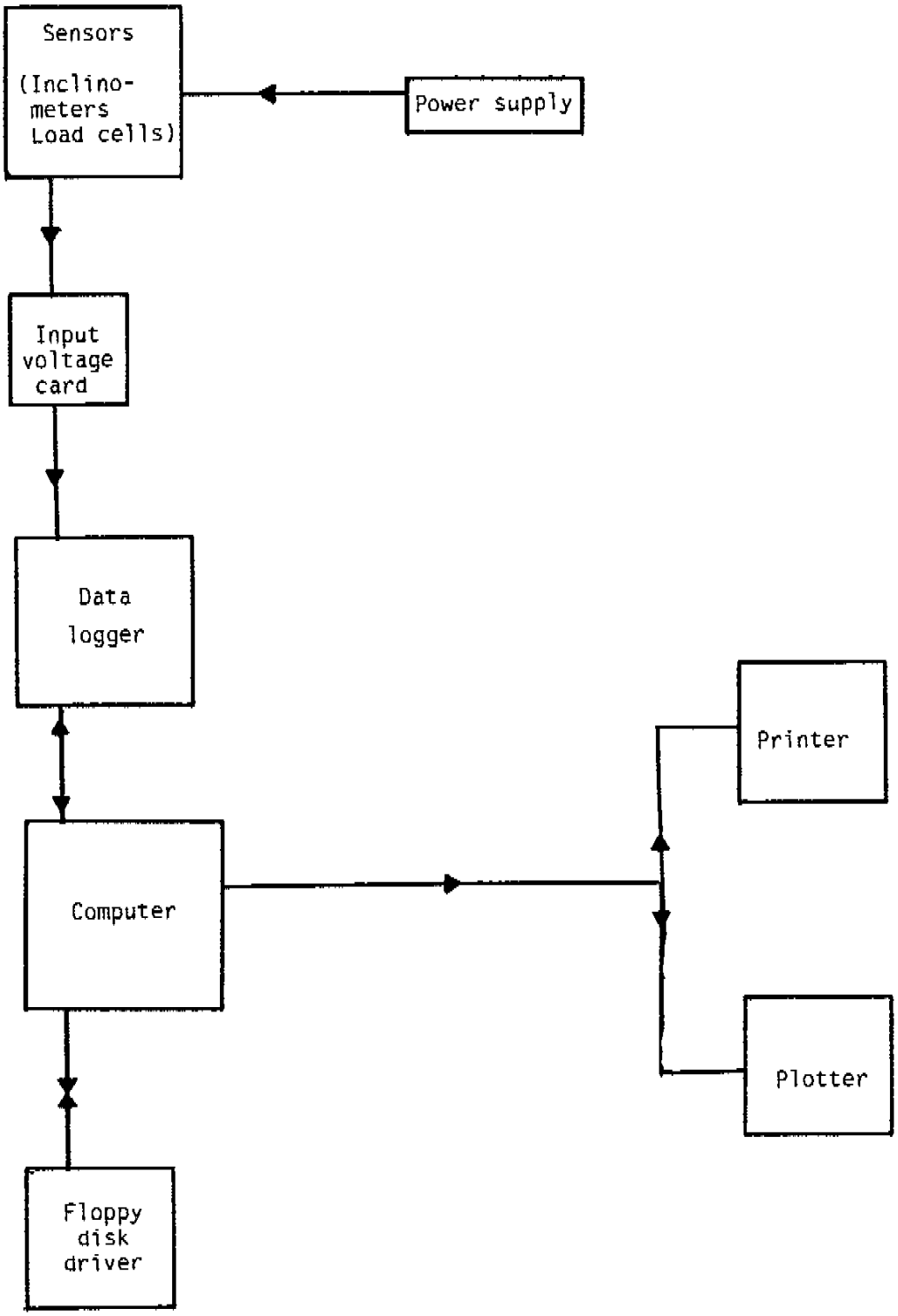
low cost model – CETS



DATA ACQUISITION SYSTEM

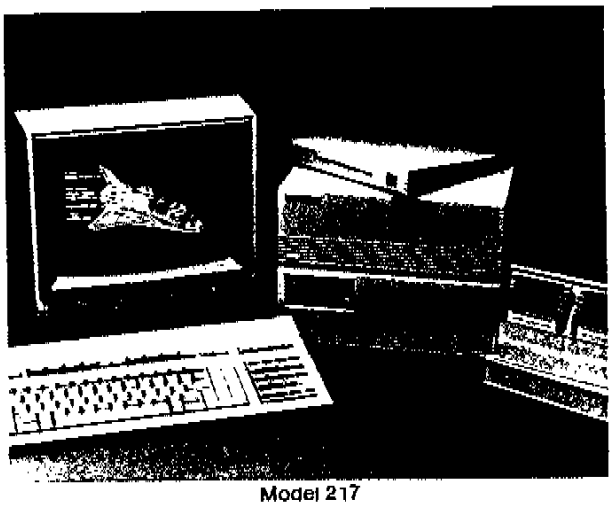
COMPUTER:	HP 9816
DATA LOGGER:	HP 3497A
INPUT VOLTAGE CARD:	HP 44427 A/B





DATA ACQUISITION SYSTEM

Model 216



Model 217

Model 236

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

The Model 236S is based on the Model 236A, includes 512 Kbyte additional RAM (640Kb RAM 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 Compilers, MC68000 Assembler, and Graphics/9000 DGL.

The Model 236CT is based on the Model 236CU base color system, and includes 1.02 Mbyte RAM, single- or multi-user HP-UX with C, FORTRAN 77, HP Pascal Compilers, MC68000 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 and integrated circuit board design, mathematical modeling, statistics, and 2-D mechanical drafting.

The Model 237H features the 12.5 MHz processor with memory management hardware and cache memory, a 431mm (17-inch) monochrome display with 1024x768 resolution and bit-mapping capabilities, built-in HP-IB floating-point math hardware, the HP-HIL keyboard, mouse, and 512 Kbyte RAM.

HP 9000 Series 200

9816S Model 216S Computer w/BASIC
9817A Model 217A Computer
9817H Model 217H Computer w/512Kb RAM, keyboard and terminal
9817L Model 217L Computer w/1 Mb RAM, keyboard, terminal & single-user HP-UX.
9920A Model 220A Modular Computer
9920U Model 220U Modular Computer w/12.5 MHz Processor
9920S Model 220S Modular Computer w/keyboard, BASIC, Pascal, 640 Kb RAM
9920T Model 220T Modular Computer w/12.5 MHz Processor, single-user HP-UX, keyboard Multi-user HP-UX
9826A Model 226A Computer
9826S Model 226S Computer w/640 Kb RAM, BASIC, Pascal, SRM
9836A Model 236A Computer
9836C Model 236C Color Computer
9836U Model 236U Computer w/12.5 MHz Processor
9836CU Model 236CU Color Computer w/12.5 MHz Processor
9836CS Model 236CS Color Computer w/640 Kb RAM, BASIC, Pascal
9836S Model 236S Computer w/640 Kb RAM, BASIC, Pascal
9836T Model 236T Computer w/12.5 MHz Processor, 1.02 Mb RAM, single-user HP-UX Multi-user HP-UX
9836CT Model 236CT Color Computer w/12.5 MHz Processor, 1.02 Mb RAM, single-user HP-UX Multi-user HP-UX
9837H Model 237H Computer w/12.5 MHz Processor, monitor, keyboard, 512Kb RAM, mouse

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 1 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 RAM-based BASIC 3.0 Language System. Includes system flexible disc and Language Extensions disc, BASIC 3.0 Language Manual Kit, and BASIC 2.0 Utilities Pack.

HP 98613B RAM-based BASIC 4.0 Language System. Includes system flexible disc and Language Extensions Disc, BASIC 4.0 Language Manual Kit and BASIC 4.0 Utilities Pack.

HP 98614A RAM-based HPL 2.0 Language System. Includes System Flexible disc, HPL 2.0 Language Manual Kit, and HPL 2.0 Utilities Pack. (Not available for Models 220 or 236C).

HP 98615B RAM-based Pascal 3.0 Language System. Includes System Flexible disc set and Pascal 3.0 Language Manual Kit.

HP 98815C RAM-based Pascal 3.1 Language System. Includes system flexible disc set and Pascal 3.1 Language Manual Kit.

HP 98670A Single-user HP-UX Operating System.

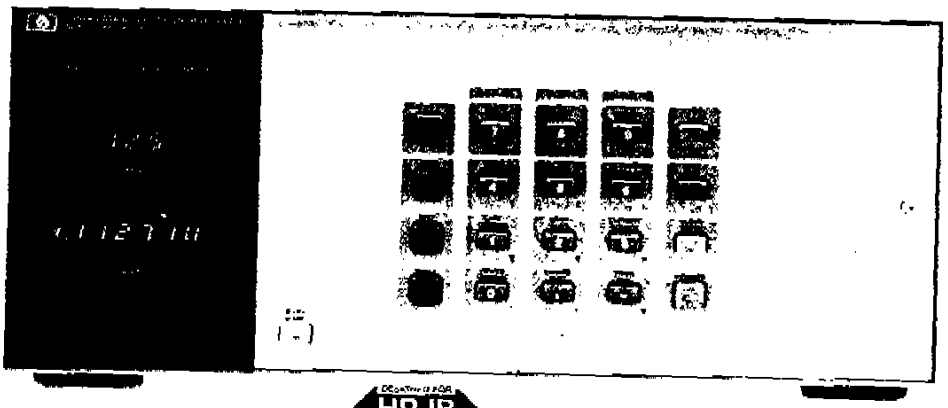
HP 98680A Multi-user HP-UX Operating System.

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

HP-IB SYSTEMS

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 very powerful instrument. 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 with or without thermocouple compensation
- —FET Multiplexer
- —Digital Input/Interrupt
- —Counters
- —Strain gage/bridge completion
- —Actuators
- —Programmable voltage and current D/As
- —Breadboard Assembly

Up to 5 assemblies can be added to a HP 3497A and the HP 3498A Extender chassis 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 gauges and other transducers. Included on the DVM is a programmable current source that allows four-terminal resistance measurements. The multiplexer assemblies 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 actuator outputs, and a DVM. By using the HP 3498A Extender, up to 1000 analog channels and 1360 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 3497A 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 timing data, 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)

Modes	Max. Time	Resolution	Accuracy
Real Time Mode:	1 year	1 second	±(.005% of time + 1 s)
Elapsed Time Mode:	10^8 seconds	1 second	±(.005% of time + 1 s)
Time Alarm Mode:	24 hours	1 second	±(.005% of time + 1 s)
Time Interval Mode:	24 hours	1 second	±(.005% of time + 1 s)
Timer Output Mode:	1 second	100 μs	± .02% of time

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

Voltmeter Range	Digits Displayed 5½ digits	4½ digits	3½ digits
0.1 V	0.007 + 5	0.01 + 2	0.1 + 1
1.0 V	0.006 + 1	0.01 + 1	0.1 + 1
10.0 V	0.006 + 1	0.01 + 1	0.1 + 1
100.0 V	0.006 + 1	0.01 + 1	0.1 + 1

Resistance Measured Through an Acquisition Assembly

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

Characteristics

Effective Resistance Range	Effective Resistance Resolution	Current Source Range	Range
100 Ω	1 mΩ	1 mA	.100000
1 kΩ	10 mΩ	100 µA	1.00000
10 kΩ	100 mΩ	100 µA	10.0000
100 kΩ	1 Ω	10 µA	10.0000

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

90 Days 23°C ± 5°C

Range Relays (Opt. 010)	Digits Displayed 5½ digits	4½ digits	3½ digits
100 Ω	.032 + 5	.035 + 2	0.125 + 1
1 kΩ	.032 + 5	.035 + 2	0.125 + 1
10 kΩ	.032 + 5	.035 + 2	0.125 + 1
100 kΩ	.031 + 2	.035 + 2	0.125 + 1

System Noise Rejection

Normal Mode Rejection (NMR): (50 or 60 Hz, ± .09%)

DVM Digits Displayed	Rejection
5½	60 dB
4½	0 dB
3½	0 dB

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

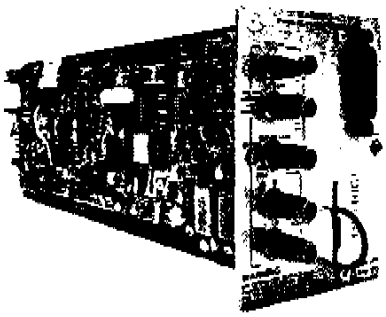
VOLTMETER CONFIGURATION

Number of Acquisition Channels (Options 10,20)		5½ Digits	4½ Digits	3½ Digits
0	AC	150 dB	90 dB	90 dB
	DC	120 dB	120 dB	120 dB
<100	AC	150 dB	90 dB	90 dB
	DC	104 dB	104 dB	104 dB
<400	AC	140 dB	80 dB	80 dB
	DC	92 dB	92 dB	92 dB
<1000	AC	130 dB	70 dB	70 dB
	DC	85 dB	85 dB	85 dB

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	85A	9825TA	9835A	9845T	1000L	1000E,F
		(Measurements/Second)					
Sequential Channels	5½	39(33)	40(33)	40(33)	40(33)	39(25)	30(25)
	4½	97(88)	100(90)	100(90)	100(90)	108(79)	88(79)
	3½	116(107)	120(111)	120(111)	120(111)	127(99)	107(99)
Random Channels	5½	16(15)	31(27)	20(18)	20(18)	21(16)	22(16)
	4½	22(21)	58(55)	30(29)	30(29)	31(28)	35(30)
	3½	23(23)	65(62)	31(31)	31(31)	33(29)	36(32)



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 milliohm resolution. Maximum speed is 300 readings per second in 3½ digit mode.

Voltmeter Specifications

Range	Max. Display	5½ Digit Resolution	Accuracy 90 Days, 23°C ± 5°C 5½ Digits	Input Z
10 V	±.119999	1 μV	±(.007% RDG + 3 counts)	10¹⁰ Ω
10 V	±1.19999	10 μV	±(.006% RDG + 1 count)	10¹⁰ Ω
100 V	±11.9999	100 μV	±(.006% RDG + 1 count)	10¹⁰ Ω
100.0 V	±119.999	1 mV	±(.006% RDG + 1 count)	10¹⁰ Ω

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

Range	23°C ±5°C
10 μA	2.5 nA
100 μA	25.0 nA
1 mA	250 nA

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

General Information

Maximum Reading Rate: (readings/second)

Auto Zero	60 Hz Operation Digits Displayed 5½	4½	3½	50 Hz Operation Digits Displayed 5½	4½	3½
ON	25	100	150	20	83	125
OFF	50	200	300	40	166	250

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

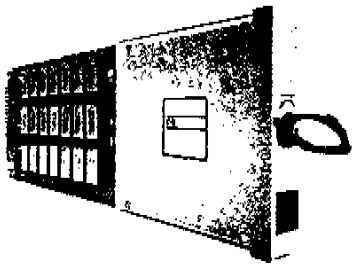
Measurement Speeds

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 I/O times to the indicated computers

60 Hz Operation (50 Hz operation)

	Number of Digits Selected	85	Computer 9826*	1000L	1000E,F
Sequential Channels using external increment	5½ digits	39 (33)	39	39 (25)	30 (25)
	4½ digits	97 (88)	103	108 (79)	88 (79)
	3½ digits	112 (107)	123	127 (99)	107 (99)
Random Channels using software	5½ digits	13 (11)	27	21 (16)	22 (16)
	4½ digits	14 (11)	51	31 (28)	35 (30)
	3½ digits	14 (11)	55	33 (29)	35 (32)

*9826 speeds for BASIC operating system



Option 010—20 Channel Relay Multiplexer

This assembly uses reed relays to multiplex signals to the DVM or other instruments. Each assembly switches 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 outputs 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: $>10^{10}$ Ω (Hi to Lo, 40°C, <60% R.H.)
Maximum switch rate: 475/second (using hardware increment)
Rated switch life at 1 VA: 10^7 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 isothermal 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, this 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

	Software	Hardware
Compatible Thermocouples	Any mixture	One of the following types: B,E,J,K,R,S,T
Measurement channels available per assembly	19	20
Reference junction compensation accuracy (23° C ± 5° C)	0.1°C	

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/85% R.H., 40°C/60% R.H.

Accuracy at Vin = 5 Volts

Bridge Type	24 Hr ±1°C	90 Day 23 ± 5°C	>90 Days 23 ± 5°C	Temperature Coefficient (0-18,28-55°C)
full	1 με	1 με	0.04 με/Mo	0.025 με/°C
1/2	4 με	5 με	0.4 με/Mo	0.3 με/°C
1/4	7 με	25 με	1.8 με/Mo	1.8 με/°C

Accuracy at Vin = 1 Volt

full	3 με	3.5 με	0.04 με/Mo	0.1 με/°C
1/2	5 με	10 με	0.9 με/Mo	0.4 με/°C
1/4	10 με	35 με	6.8 με/Mo	1.8 με/°C

Accuracy at Vin = 100 mV

full	20 με	35 με	0.04 με/Mo	0.8 με/°C
1/2	40 με	75 με	0.9 με/Mo	1.7 με/°C
1/4	80 με	150 με	6.8 με/Mo	3.5 με/°C

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 lead-wire 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 Kohms, ±0.27%
(internal) = 79.81 Kohms, ±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 ≤ +4.7 με/ohm (for 120 and 350 ohm gages, full bridge). The full bridge internal shunt value will be larger than predicted by 2.6 με ± 2.4 με due to the relay card resistance (note that this resistance acts like an additional leadwire resistance of between 0.05 ohms and 1.1 ohms).

Excitation Supply Requirements:

Linear Regulated Supply

Vs max: ±5.4 volts dc

Is: 250 mA per 10 channels (120 ohm gages, 1/2 bridge)
80 mA per 10 channels (350 ohm gages, 1/2 bridge)

These figures assume a gage factor of 2, Rg = ±0.5%

Maximum self-heating offset due to change in the number of gages on one assembly. 0.3 με per gage (Vs = +5, Rg = 120 ohm, 1/4 bridge)

Maximum self-heating offset due to 10% change in supply voltage: 0.38 με (Vs = +5, Rg = 120 ohm, 1/4 bridge).

Isolation Voltage:

≥ 170 V peak between any terminal and chassis.

Shunt Calibration:

Conditions: 1/4 bridge, Rg = ±0.5%, Gf = +2

Nominal Shunt Calibration Values

	Nominal	5V	1V	1V	Leadwire Adder
Internal Shunt	+3123 με	±23 με	±30 με	±102 με	See Note 5
External Shunt 120 ohms	-1023 με	±23 με	±29 με	±101 με	≤ 25.2 με/ohm max absolute
External Shunt 350 ohms	-2943 με	±37 με	±44 με	±116 με	≤ -25.2 με/ohm max absolute

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.

Number of Channels	ECMR (db)
≤ 50	150
≤ 150	144
≤ 250	140
≤ 350	138
≤ 450	136
≤ 500	134

Additional Strain Error Due At 40°C, 95% R.H.:

Strain error (due to leakage current flowing into LO common) is given by

$$\epsilon \text{ error} = (I \text{ leak} \cdot 1428)/(N \cdot Gf \cdot V \text{ in})$$

Where N = 1 for 1/4 Bridge
2 for 1/2 Bridge
4 for Full Bridge

Gf = Gage factor

I leak = 100 nA/ card + 100 nA/Mainframe (or Extender)

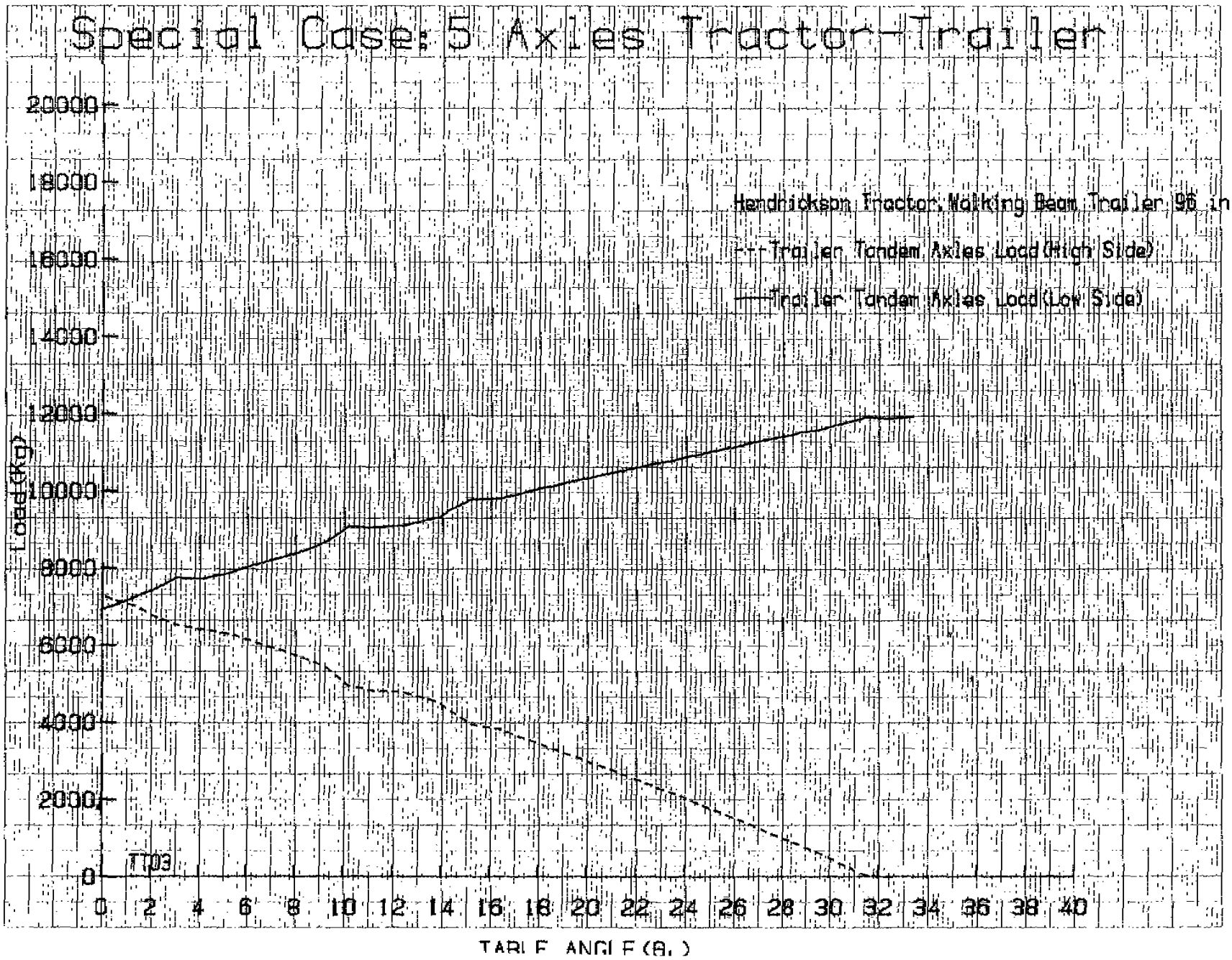
APPENDIX 3

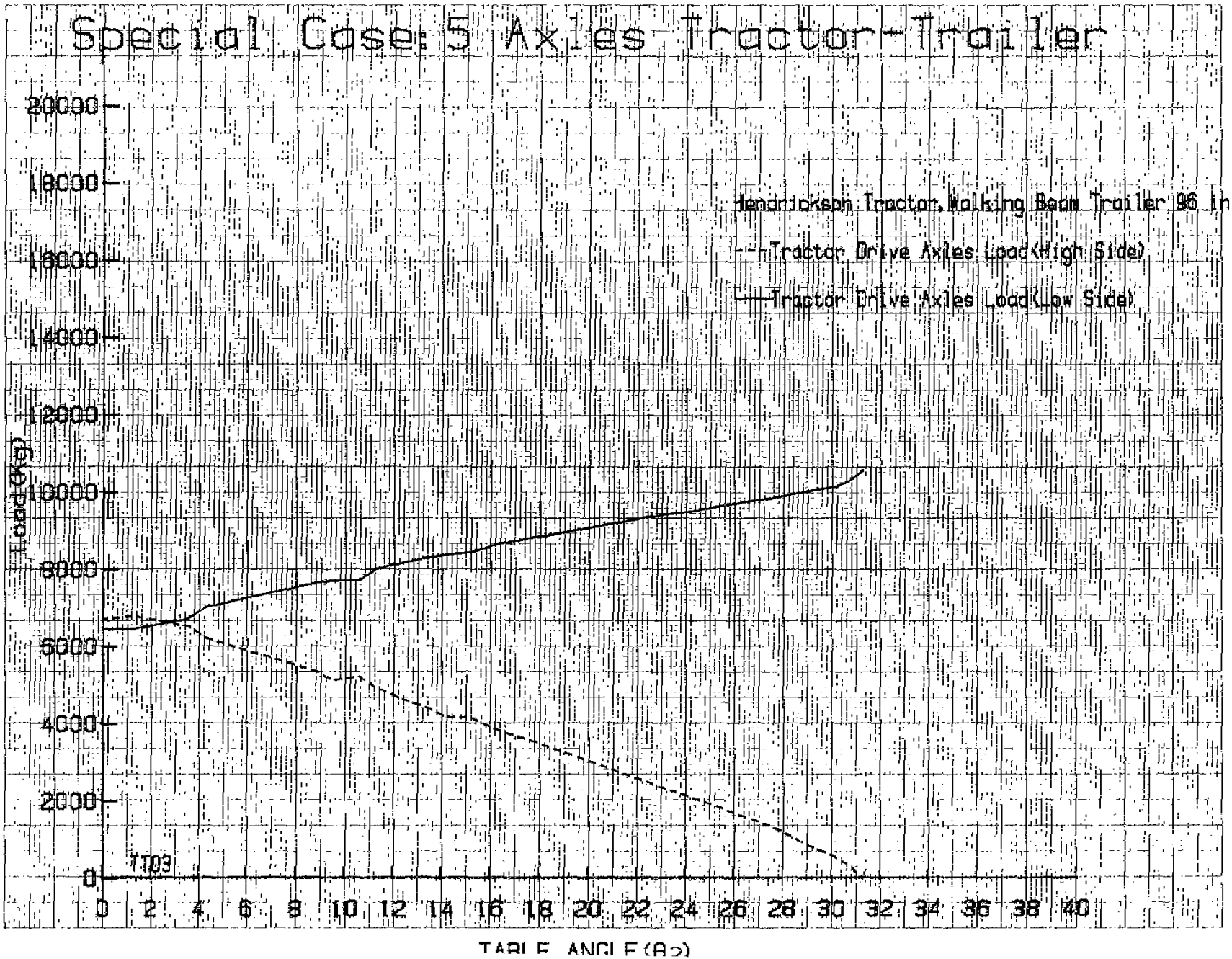
TEST DATA SUMMARIES

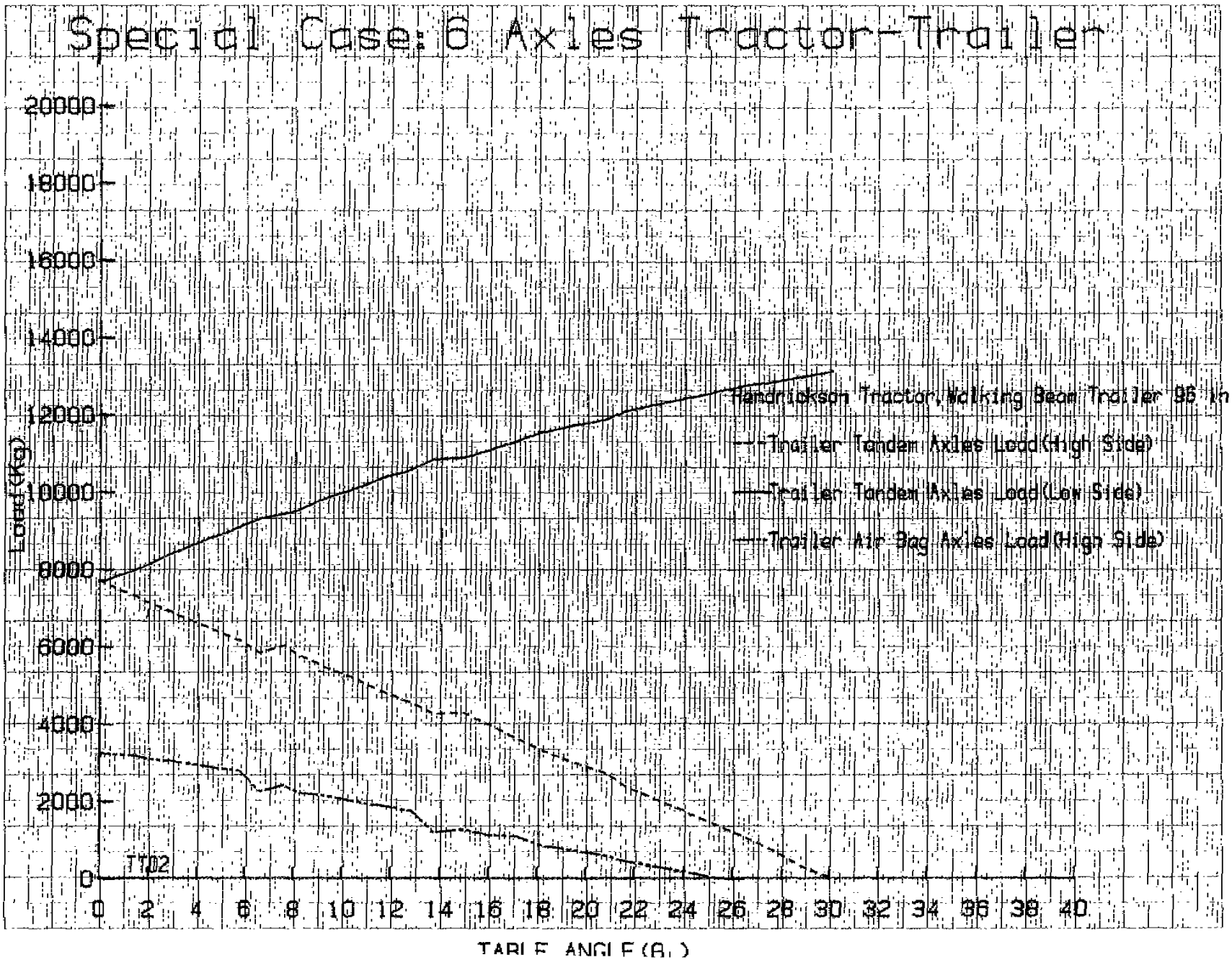
Task One:Baselines Vehicles

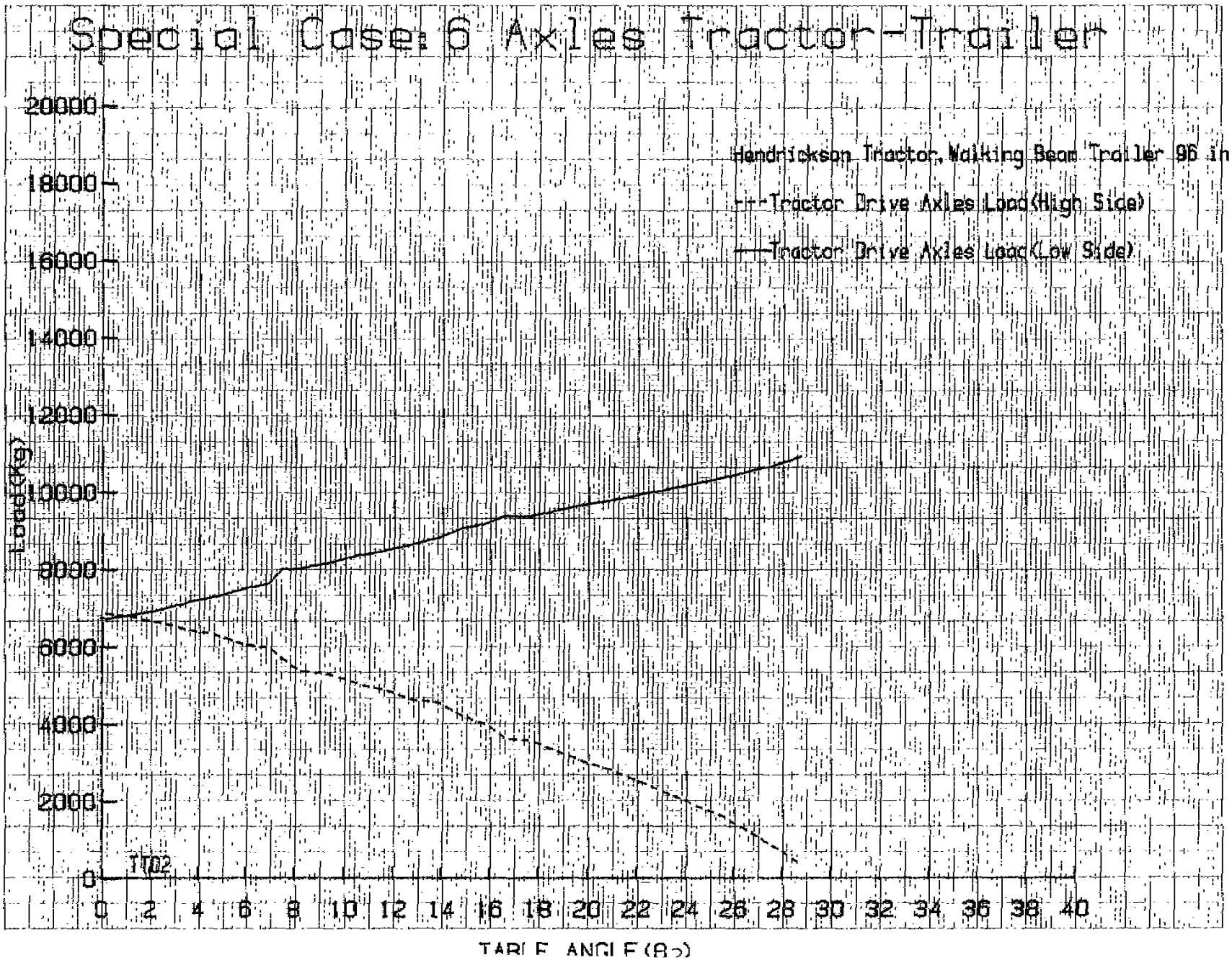
DESCRIPTION

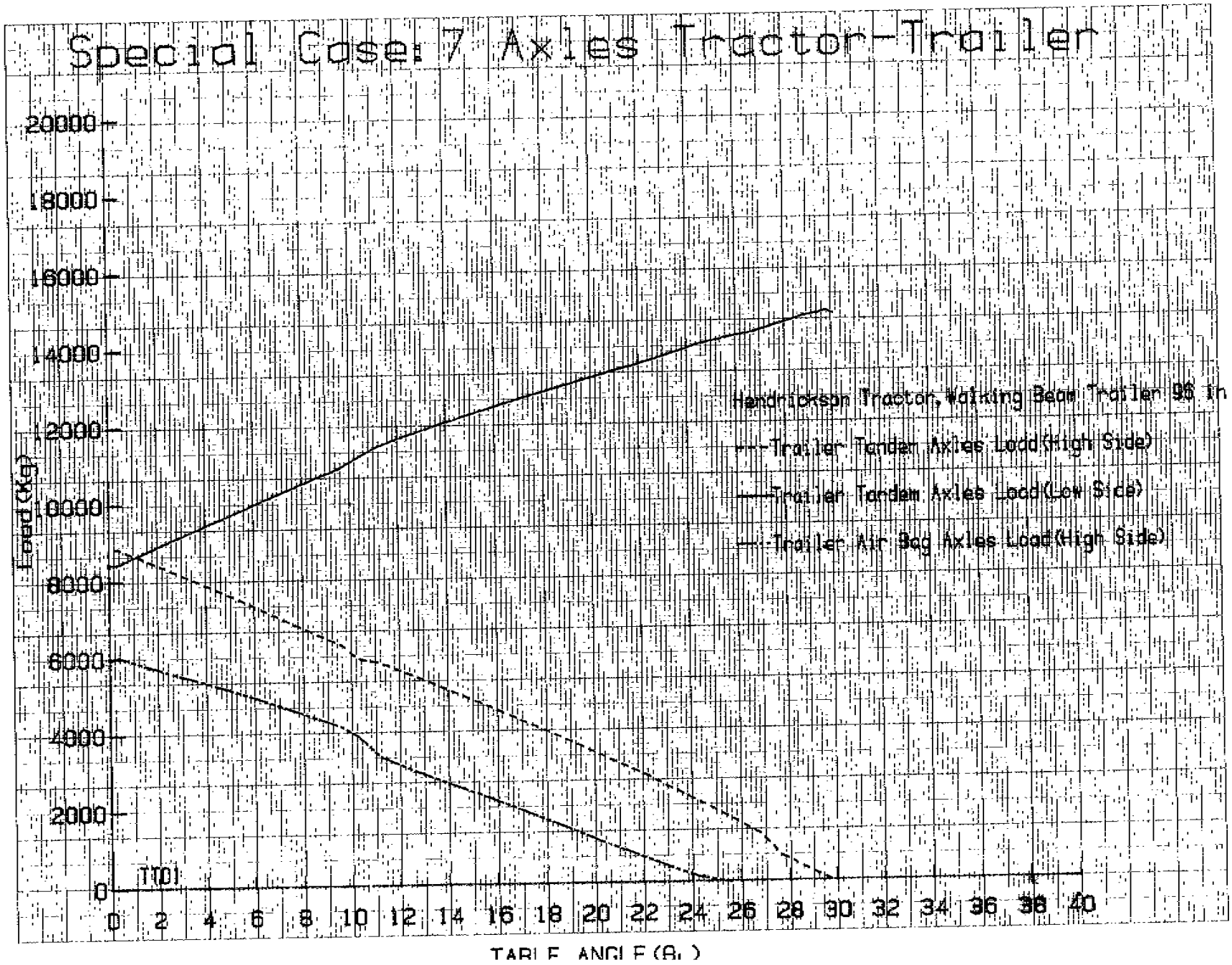
TRACTOR TYPE	1975 Freightliner
TRAILER TYPE	14,78M Flat bed
TRACTOR LENGTH	6,84M
TRAILER LENGTH	14,78M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 24.5 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Fruehauf 4 Springs
SUSPENSION TYPE ON LIFTS AXLES	2 Neway AR95 Lift Axle
AXLE SPREAD ON TRACTOR	3,47M 1,85M
AXLE SPREAD ON TRAILER	2,74M Each
TRACK WIDTH ON TRACTOR	2,43M
TRACK WIDTH ON TRAILER	2,42M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,30M
AMBIENT TEMPERATURE	12°c

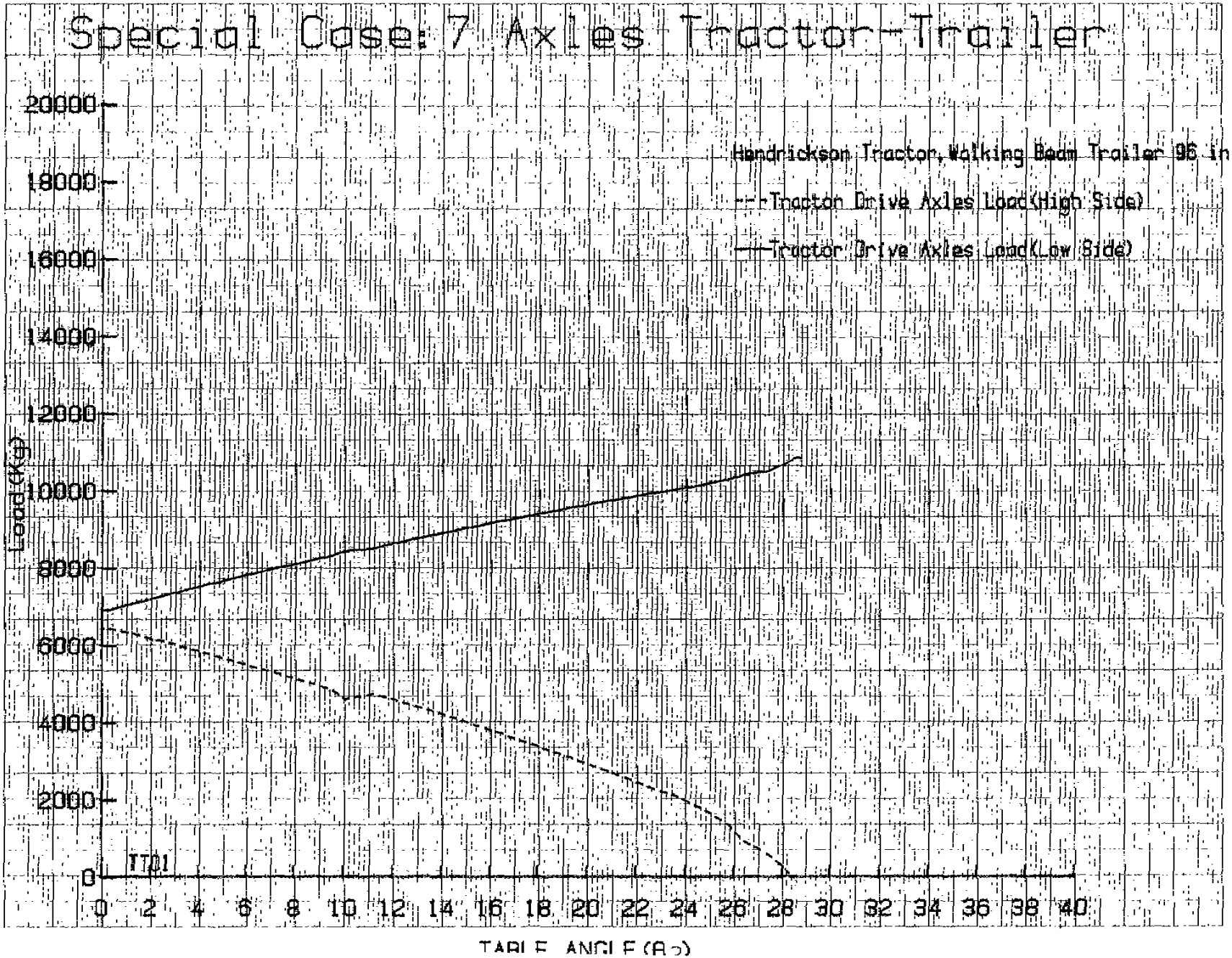

Special Case: 5 Axles Tractor-Trailer
Hendrickson Tractor Walking Beam Trailer 96 in
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(θ,)


Special Case: 5 Axles Tractor-Trailer
Hendrickson Tractor, Walking Beam Trailer 96 in
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load(kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(A)


Special Case: 6 Axles Tractor-Trailer
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(B.)
Hendrickson Tractor,Walking Beam Trailer 96 in
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Trailer Air Bag Axles Load(High Side)

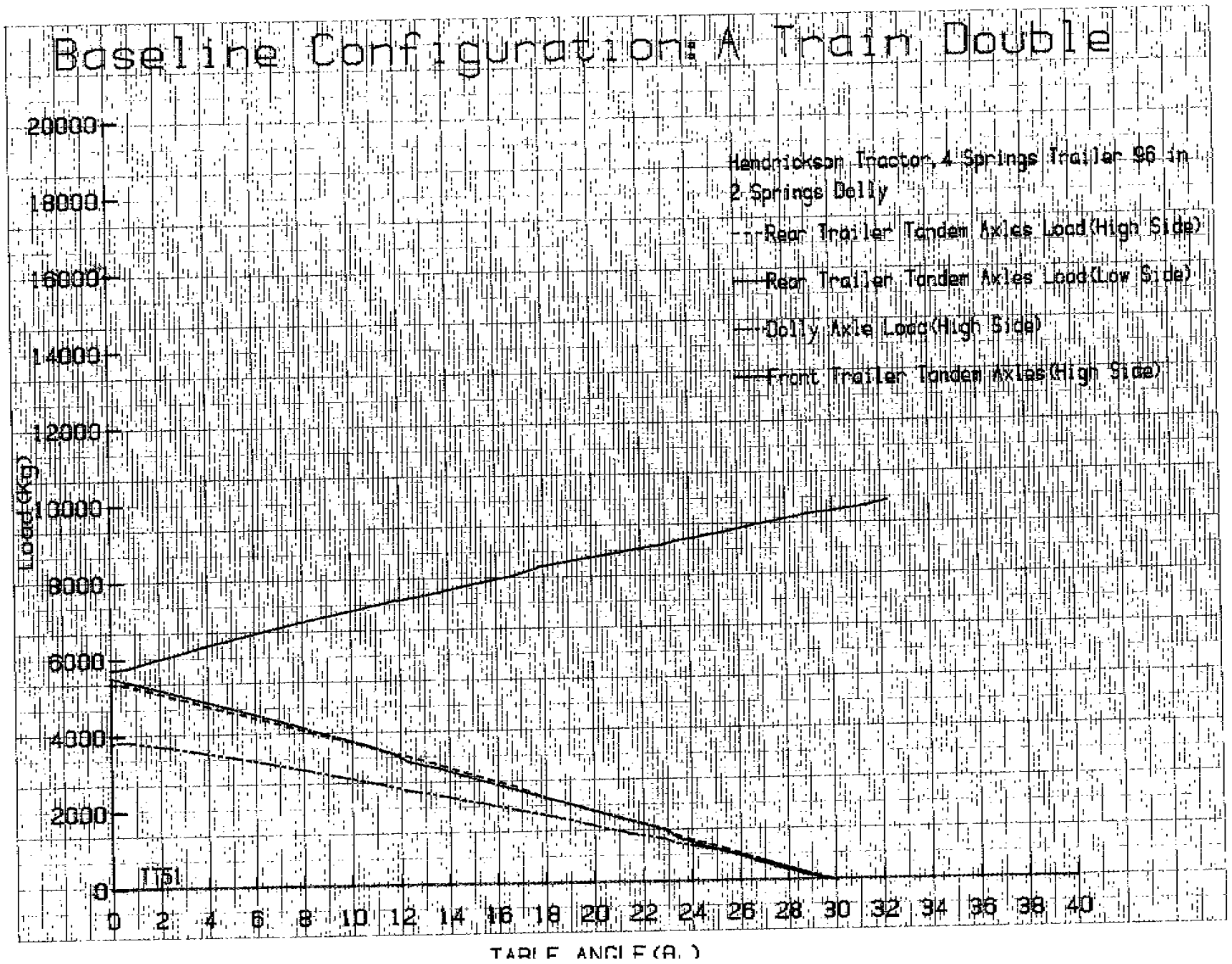

Special Case: 6 Axles Tractor-Trailer
Hendrickson Tractor, Walking Beam Trailer 96 in
---Tractor Drive Axles Load(High Side)
——Tractor Drive Axles Load(Low Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT02
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TARI E ANGLE (θ)

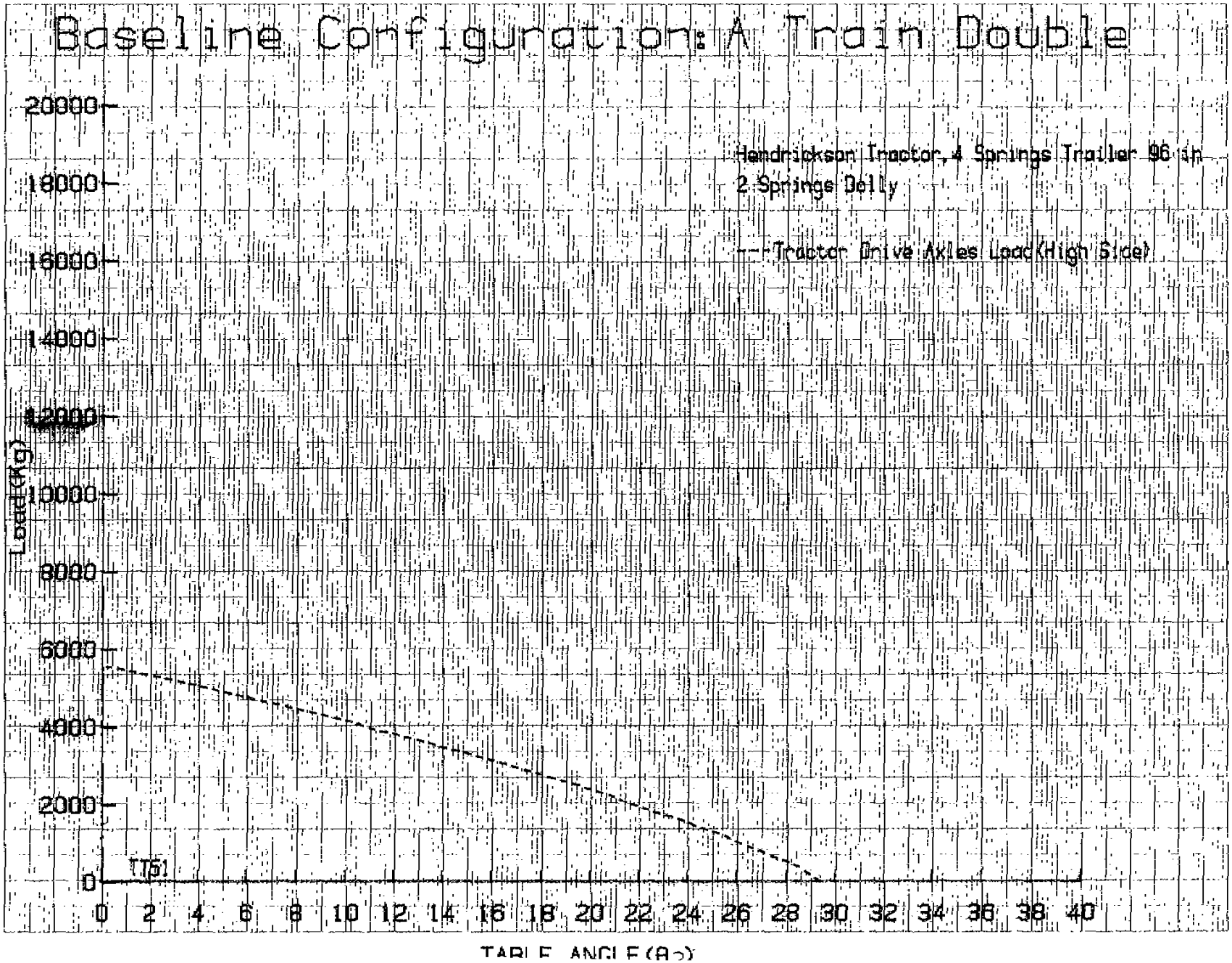

Special Case: 7 Axles Tractor-Trailer
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TRACTOR ANGLE (θ1)
Hendrickson Tractor, Walking Beam Trailer 96 in
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Trailer Air Bag Axles Load(High Side)



DESCRIPTION

TRACTOR TYPE	1975 Freightliner
TRAILER TYPE	A-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 RTE 440
SUSPENSION TYPE ON TRAILERS	4 Springs Reyco 218
SUSPENSION TYPE ON DOLLY	2 Springs Reyco 218
AXLE SPREAD ON TRACTOR	3,47M 1,85M
AXLE SPREAD ON TRAILER	1,24M 2,90M 4,96M 1,24M
TRACK WIDTH ON TRACTOR	2,43M
TRACK WIDTH ON TRAILER	2,43M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,32M
AMBIENT TEMPERATURE	10°c

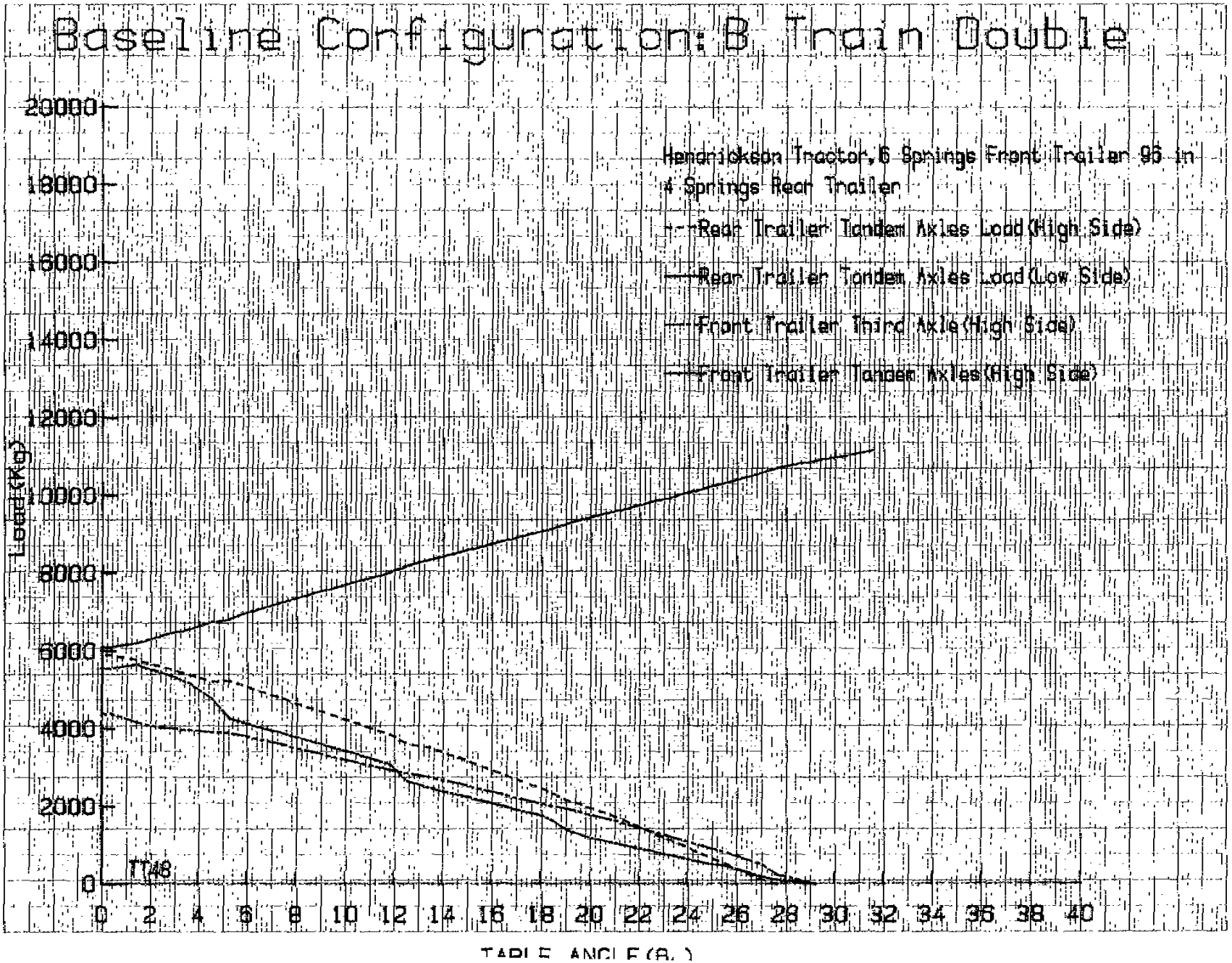

Baseline Configuration: A Train Double
Hendrickson Tractor, 4 Springs Trailer 96 in
2 Springs Dolly
Rear Trailer Tandem Axles Load(High Side)
Rear Trailer Tandem Axles Load(Low Side)
Dolly Axle Load(High Side)
Front Trailer Tandem Axles(High Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(A.)

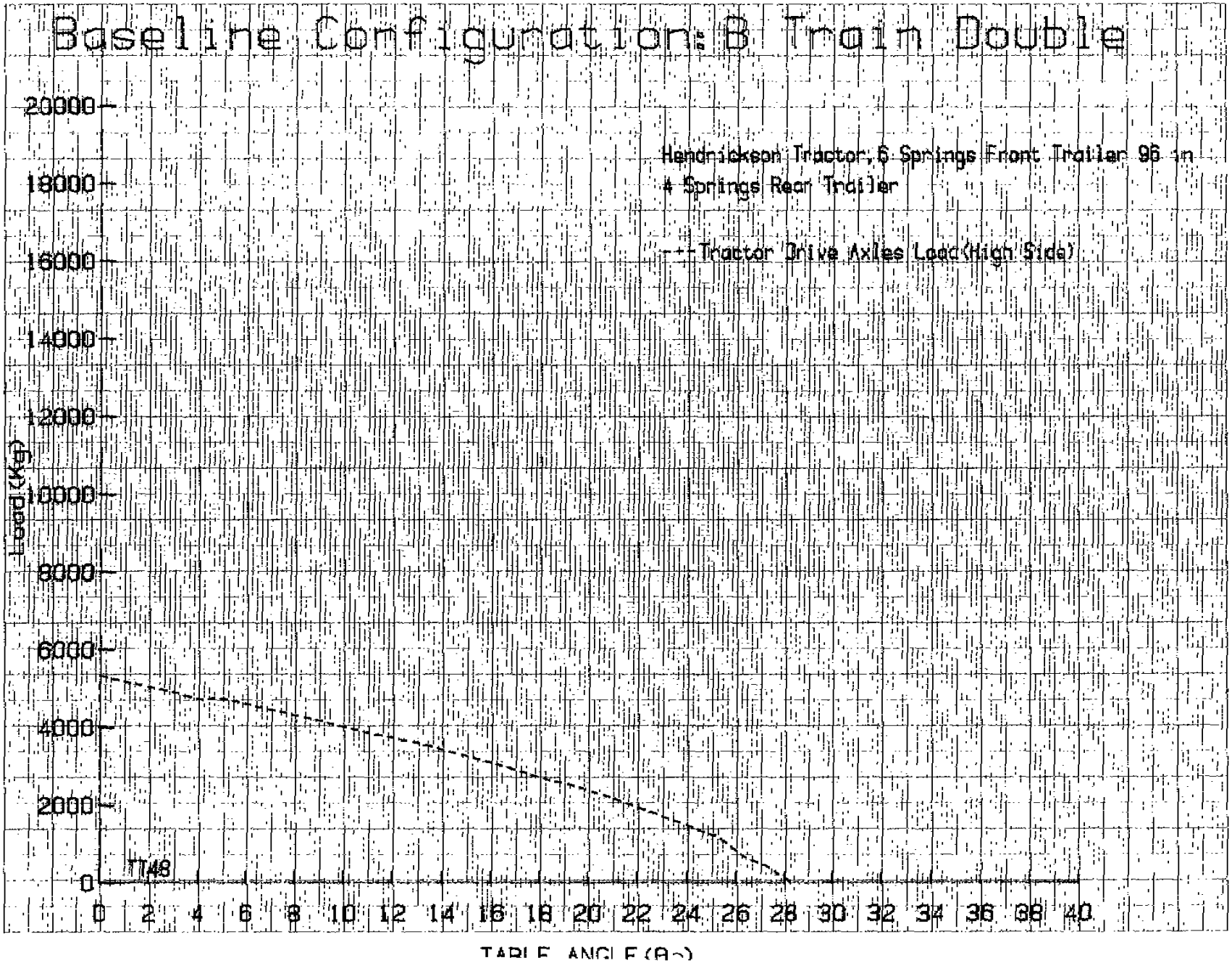

Baseline Configuration: A Train Double
Hendrickson Tractor, 4 Springs Trailer 96 in
2 Springs Dolly
---Tractor Drive Axles Load(High Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT61
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(Ao)

Task One:Baselines Vehicles

DESCRIPTION

TRACTOR TYPE	1975 Freightliner
TRAILER TYPE	B-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 RTE 440
SUSPENSION TYPE ON FRONT TRAILER	6 Springs (Triaxle)
SUSPENSION TYPE ON REAR TRAILER	4 Springs Reyco 21B
AXLE SPREAD ON TRACTOR	3,47M 1,85M
AXLE SPREAD ON TRAILER	1,52M 1,52M 4,92M 1,79M
TRACK WIDTH ON TRACTOR	2,43M
TRACK WIDTH ON TRAILER	2,43M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,32M
AMBIENT TEMPERATURE	5°C

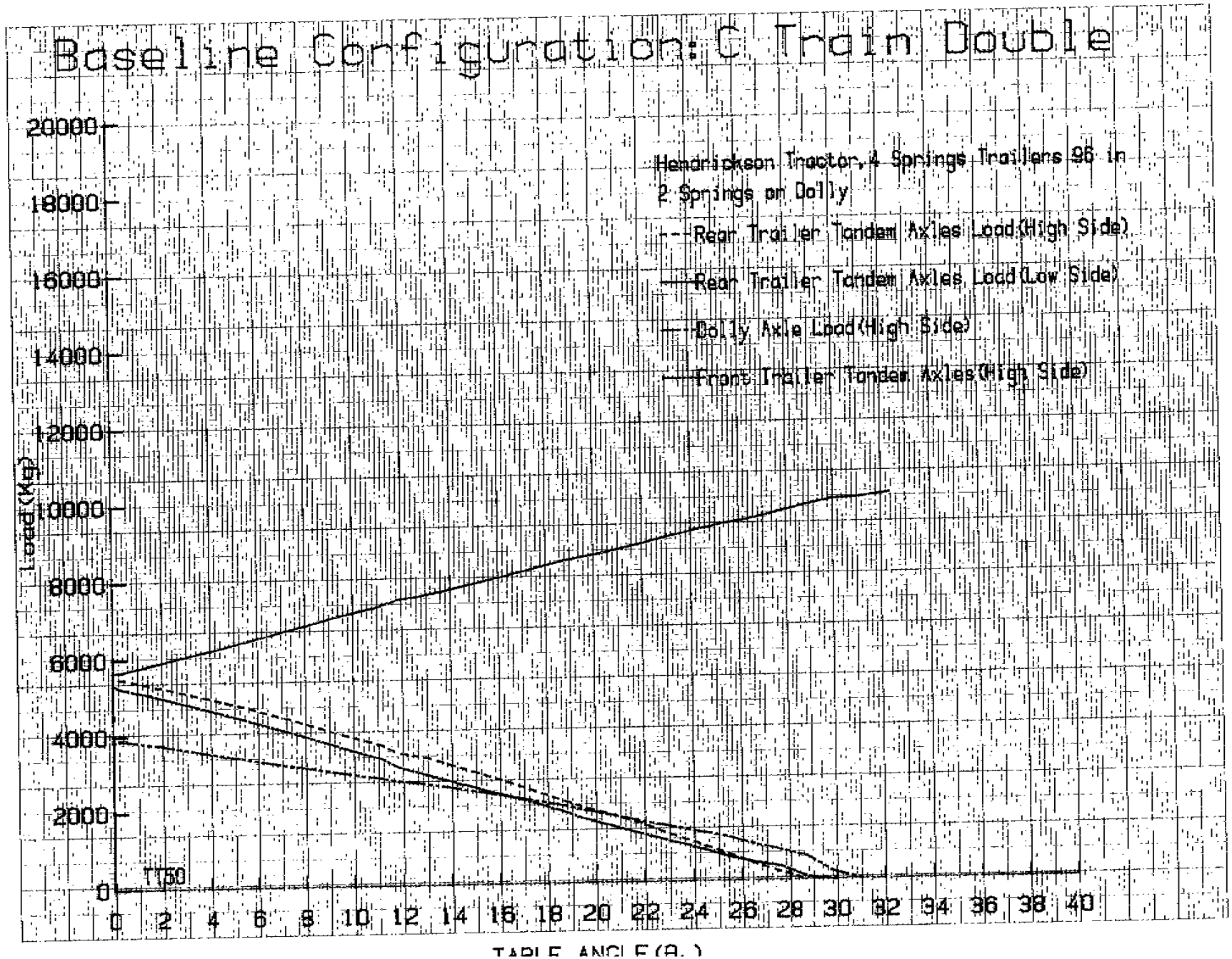


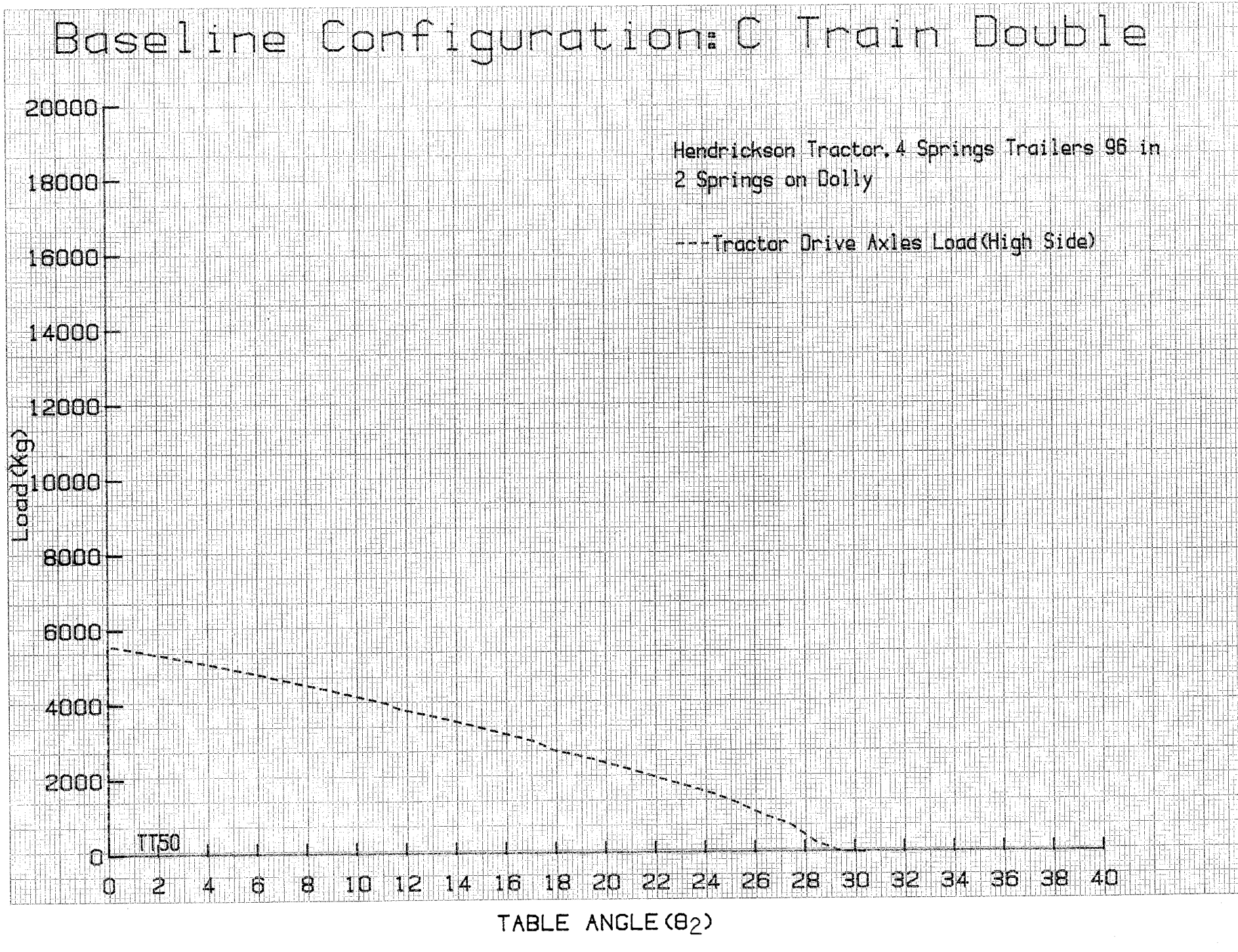


Task One:Baselines Vehicles

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 RTE 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	2,43M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,32M
AMBIENT TEMPERATURE	13°c


Baseline Configuration: C Train Double
Hendrickson Tractor,4 Springs Trailiens 96 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)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT50
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(A.)

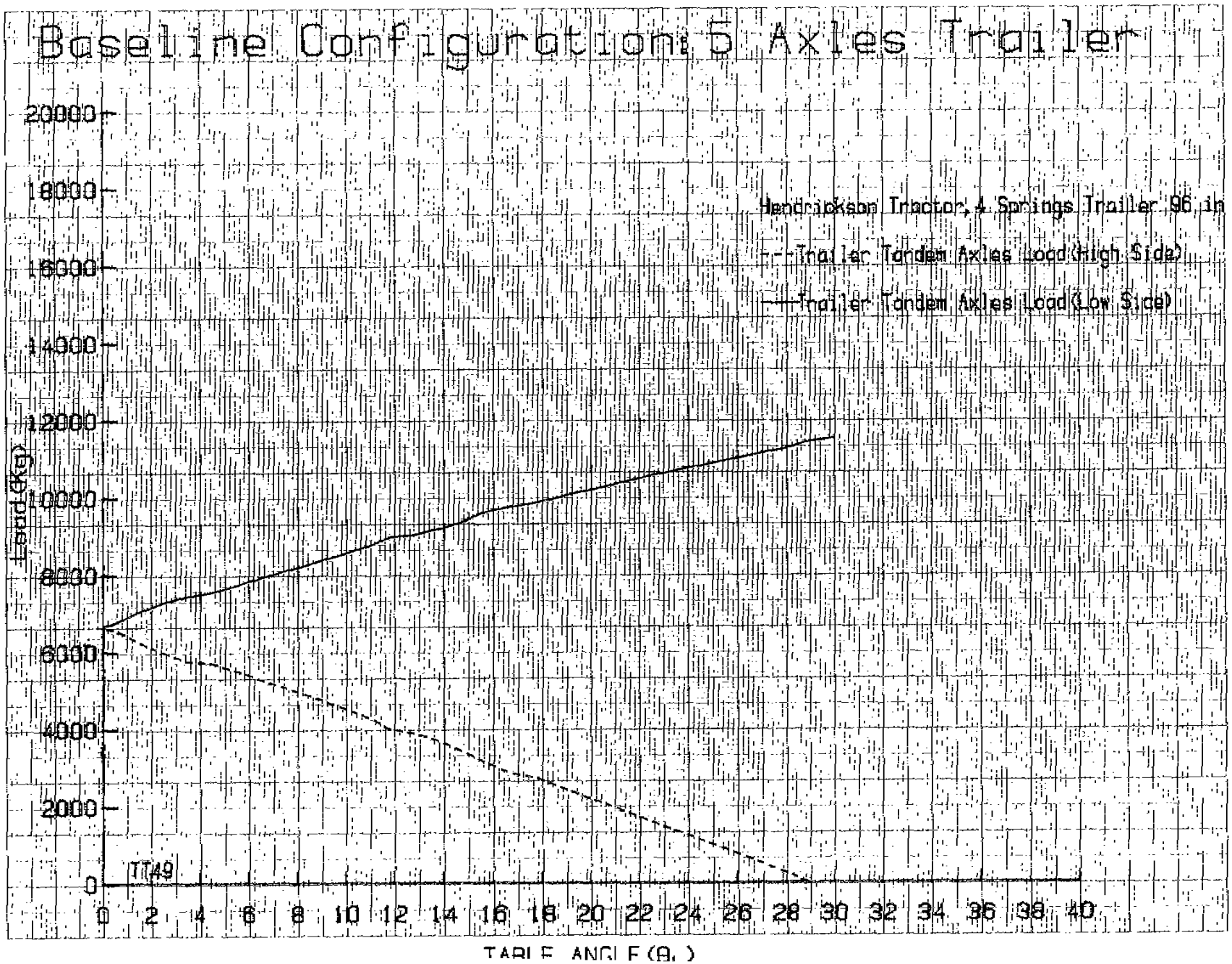

Baseline Configuration: C Train Double
Hendrickson Tractor, 4 Springs Trailers 96 in
2 Springs on Dolly
---Tractor Drive Axles Load(High Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT50
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ_2)

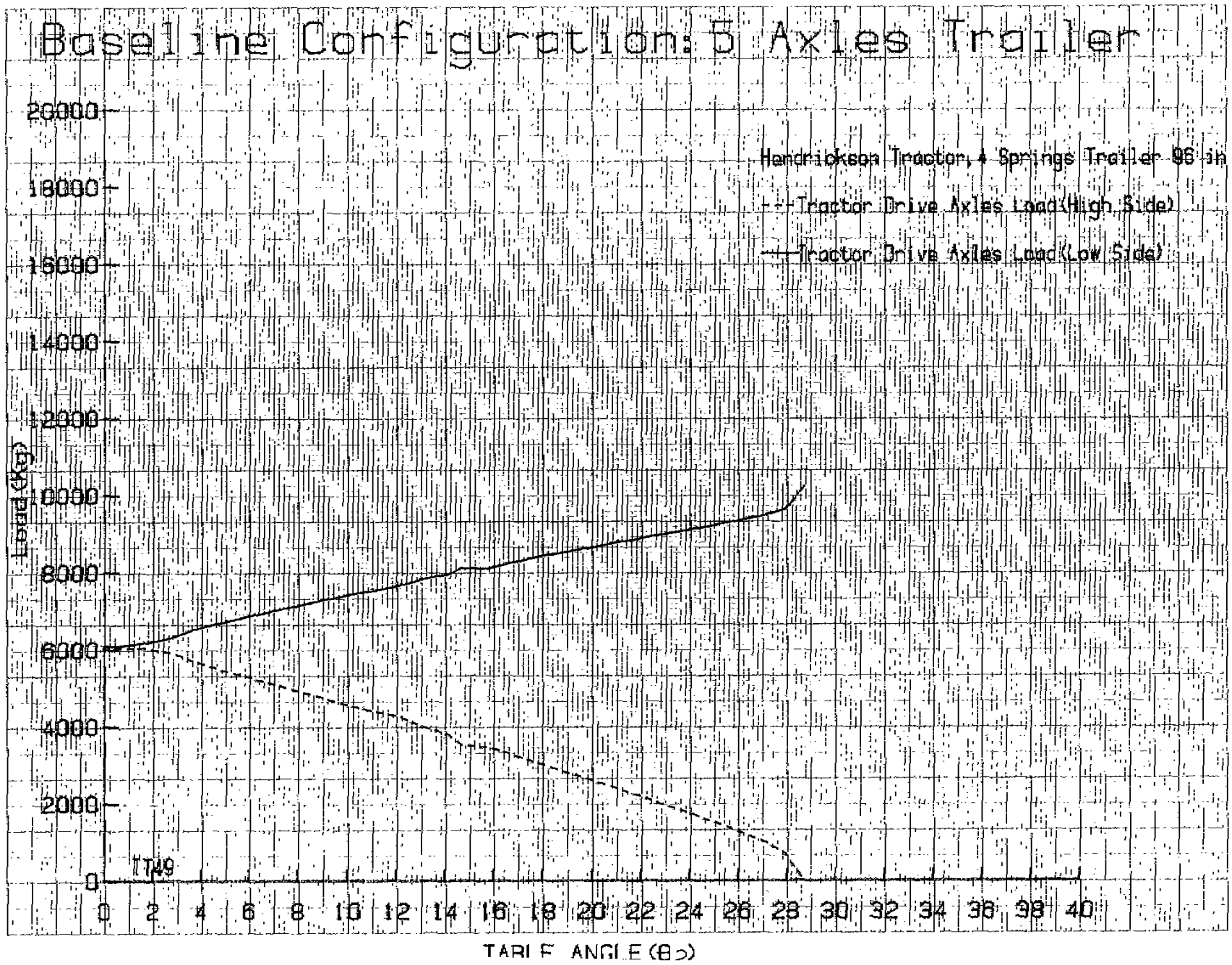
hh

Task One:Baselines Vehicles

DESCRIPTION

TRACTOR TYPE	1975 Freightliner
TRAILER TYPE	Ram 13,71M Flat Bed
TRACTOR LENGTH	6,84M
TRAILER LENGTH	13,71M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 24.5 XZA
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Reyco 21B
AXLE SPREAD ON TRACTOR	3,47M 1,35M
AXLE SPREAD ON TRAILER	1,37M
TRACK WIDTH ON TRACTOR	2,43M
TRACK WIDTH ON TRAILER	2,43M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,32M
AMBIENT TEMPERATURE	10°C

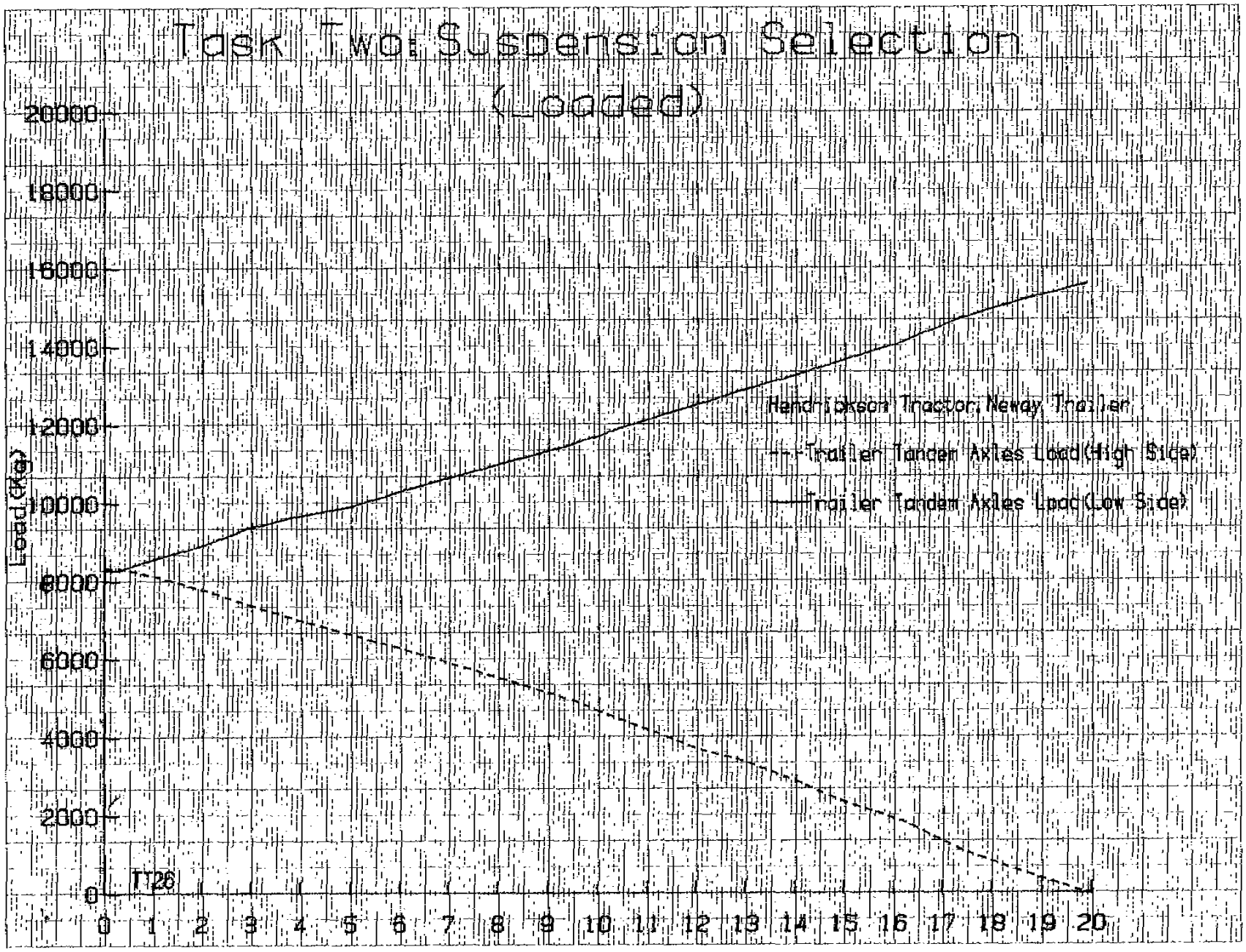

Baseline Configurbtion: 5 Axles Trailer
Hendrickson Tractor, 4 Springs Trailer 96 in
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT49
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(A.)


Baseline Configuration: 5 Axles Trailer
Hendrickson Tractor, 4 Springs Trailer 96 in
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TANGENT ANGLE (θ)

Task Two:Suspension Selection

DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	8,02M
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	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Neway AR95
AXLE SPREAD ON TRACTOR	5,12M 1,55M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,2sM
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT26
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θt)
Hendrickson Tractor, Neway Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)

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 manoeuver 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

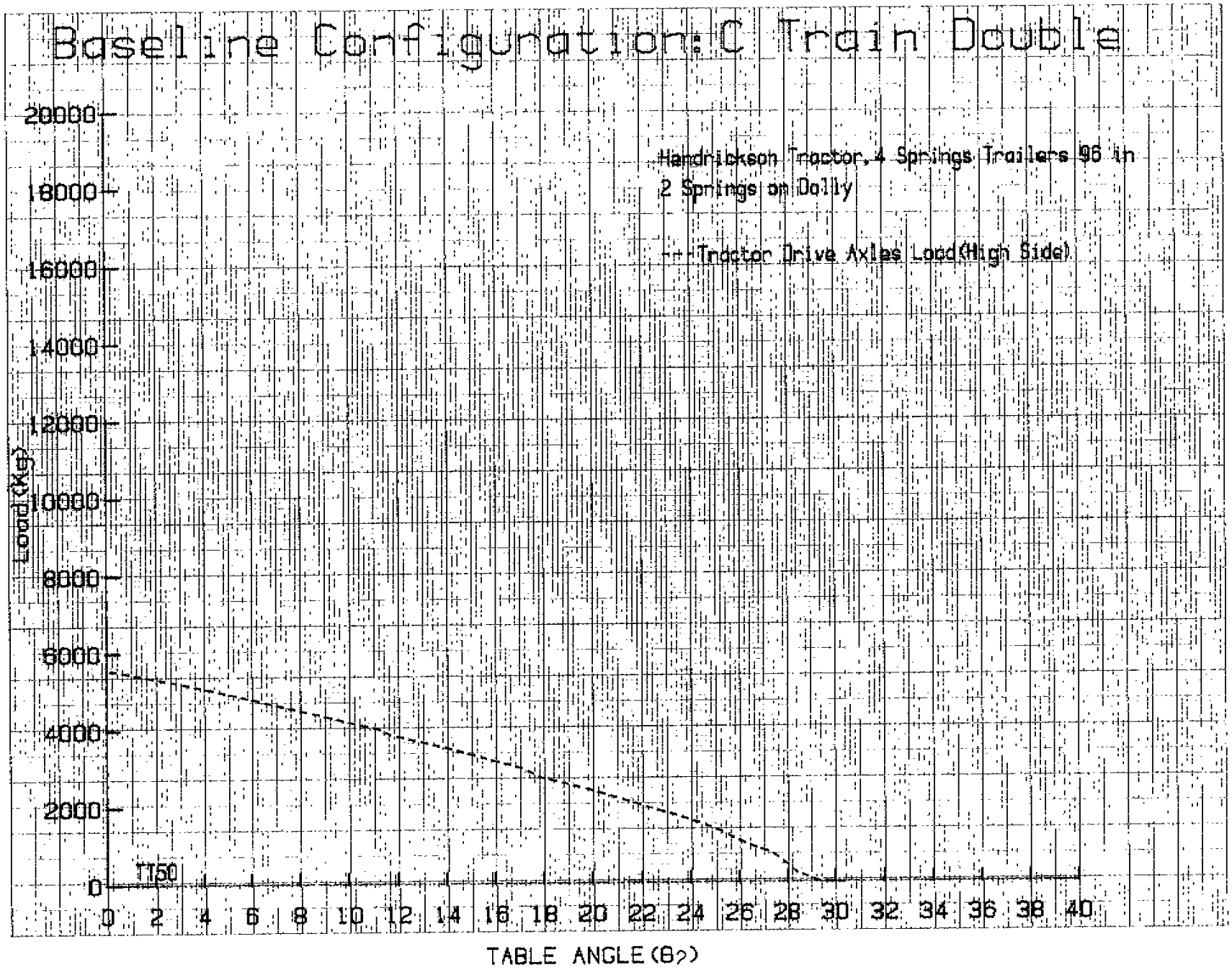
The resistance to roll provided by the trailer suspension was observed to have less influence on the roll threshold of the combination than the tractor suspension. Three different trailer suspensions were tested and an average variation on roll threshold of 5% was observed.

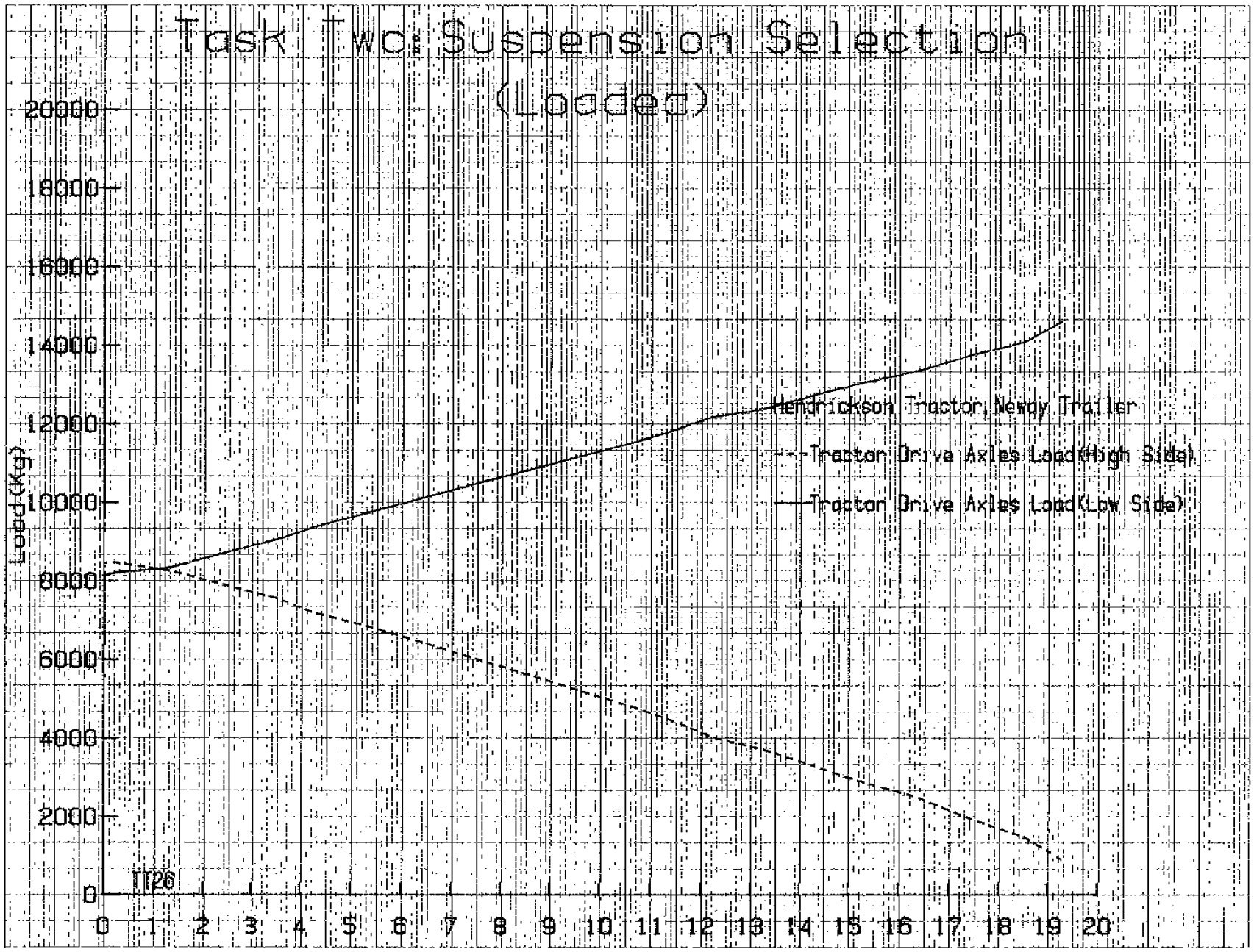
5. Fifth Wheel Vertical Slack

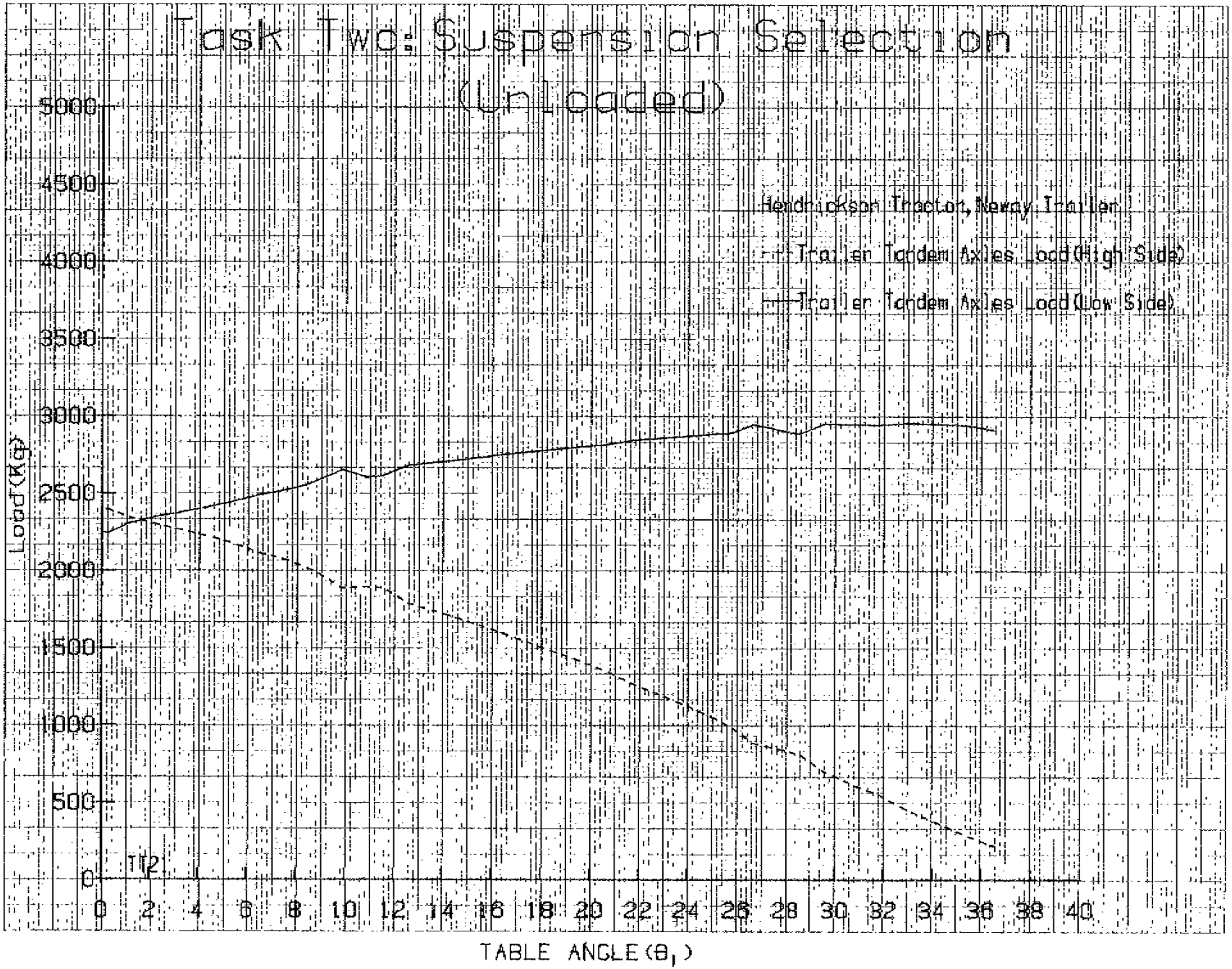
Removal of the vertical slack normally present between the fifth wheel and the trailer skid plate improved the roll threshold by about 4%.

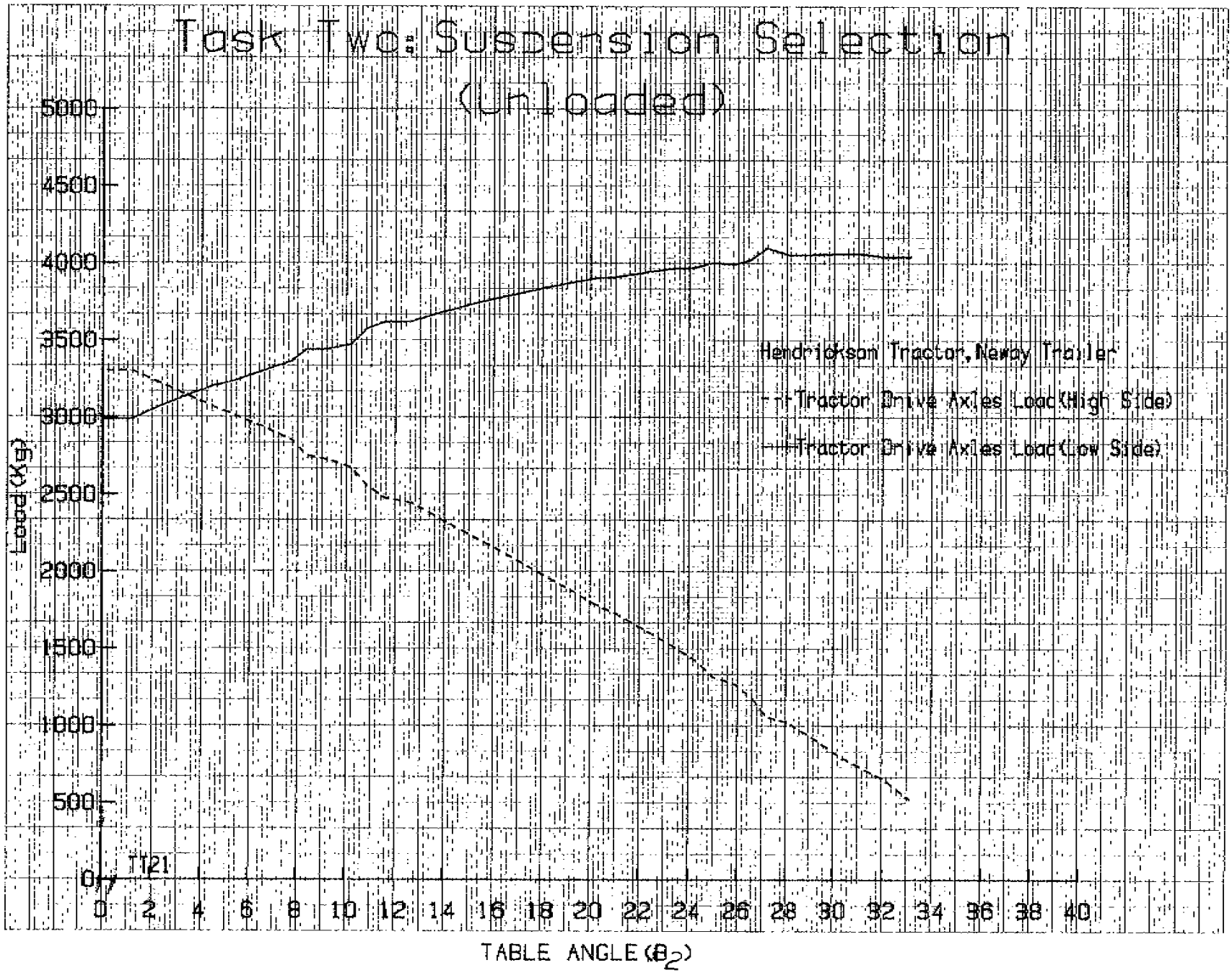
6. Tire Choice

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.


Baseline Configuration:C Train Double
Hendrickson Tractor,4 Springs Trailers 96 in
2 Springs on Dolly
Tractor Drive Axles Load(High Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1750
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ2)



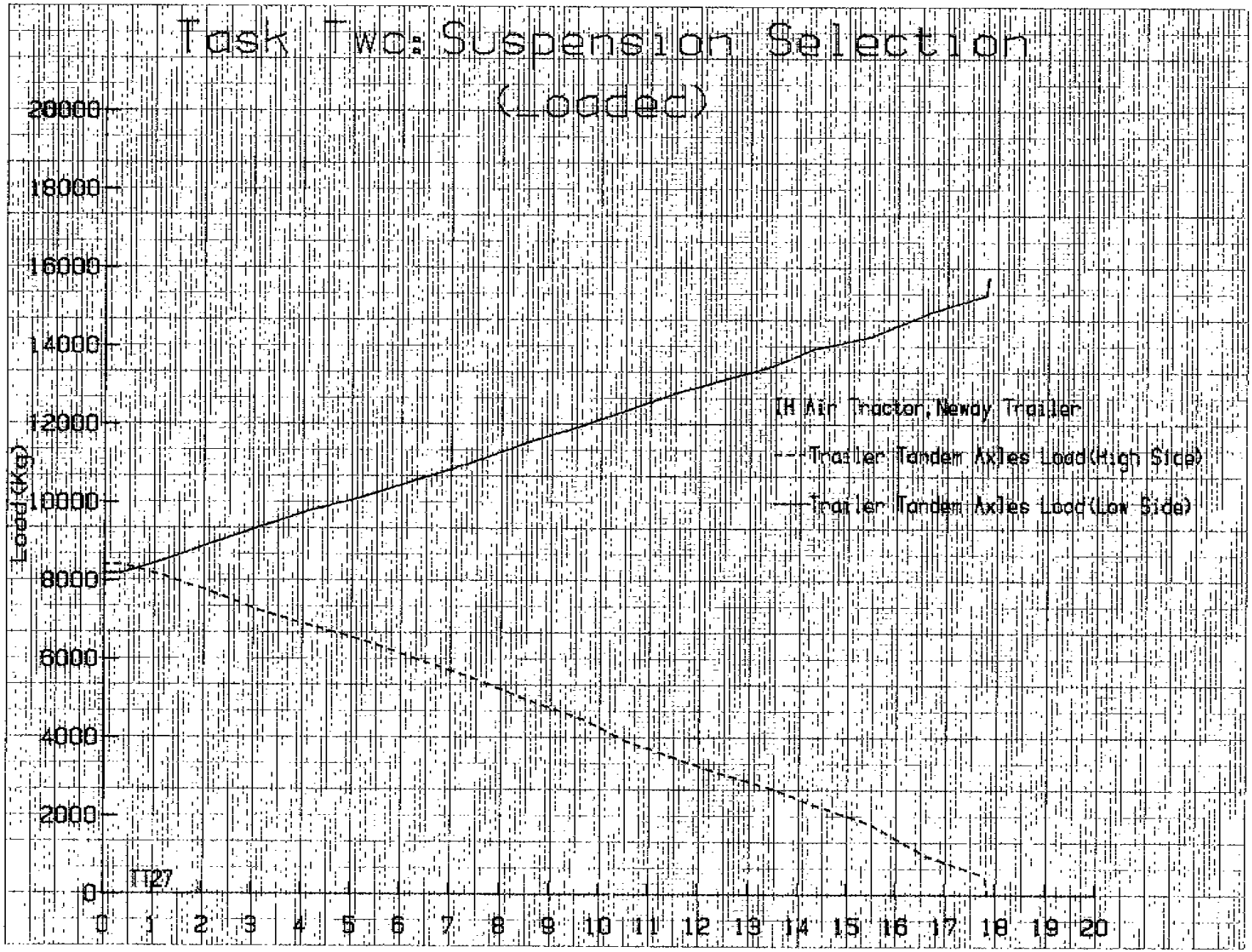

Task Two: Suspension Selection
(Unloaded)
Hendrickson Tractor, Neway Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1/2
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
TABLE ANGLE(θ1)

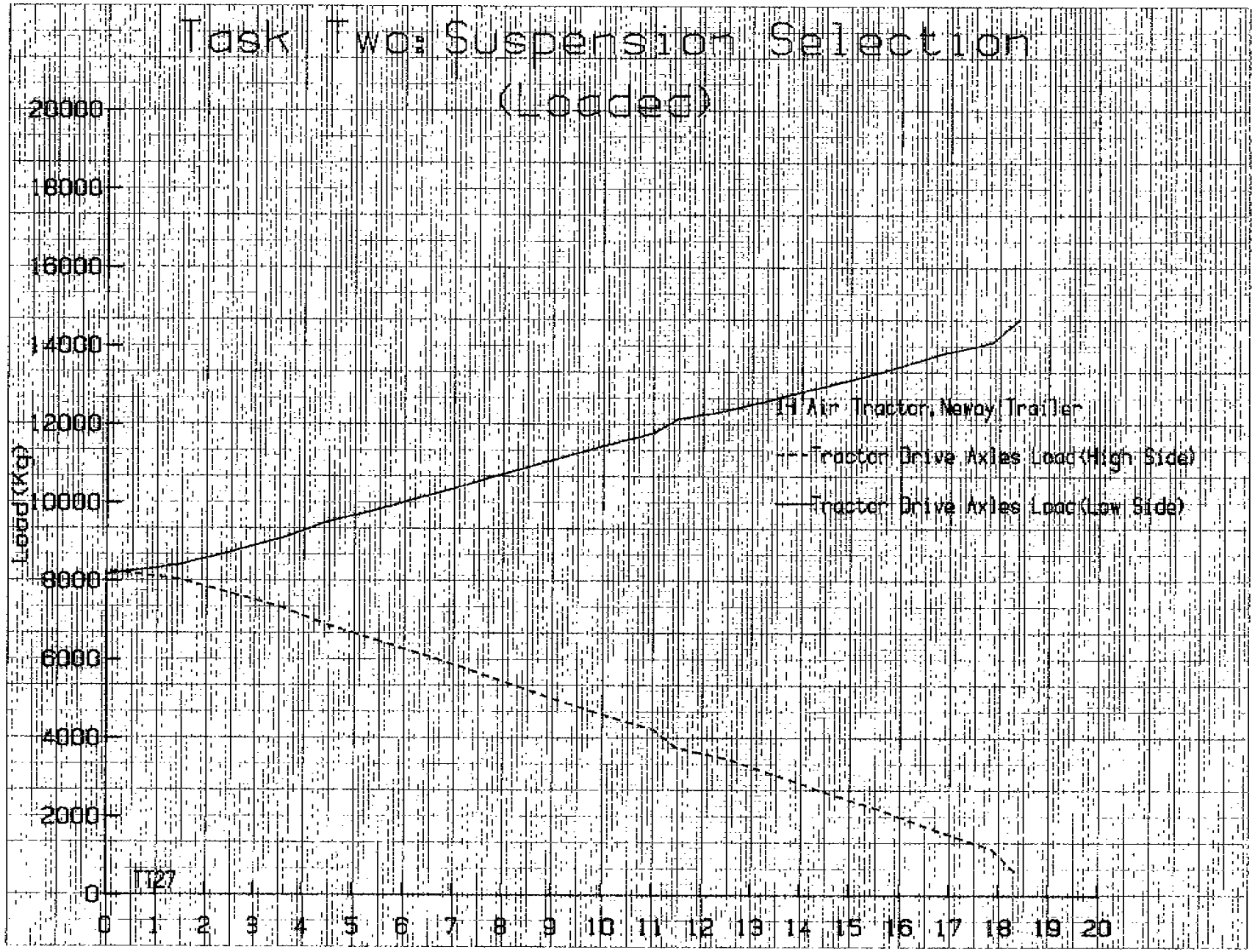

Task Two: Suspension Selection
(Unloaded)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
T121
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ_2)
Hendrickson Tractor, Neway Trailer
Tractor Drive Axles Load (High Side)
Tractor Drive Axles Load (Low Side)

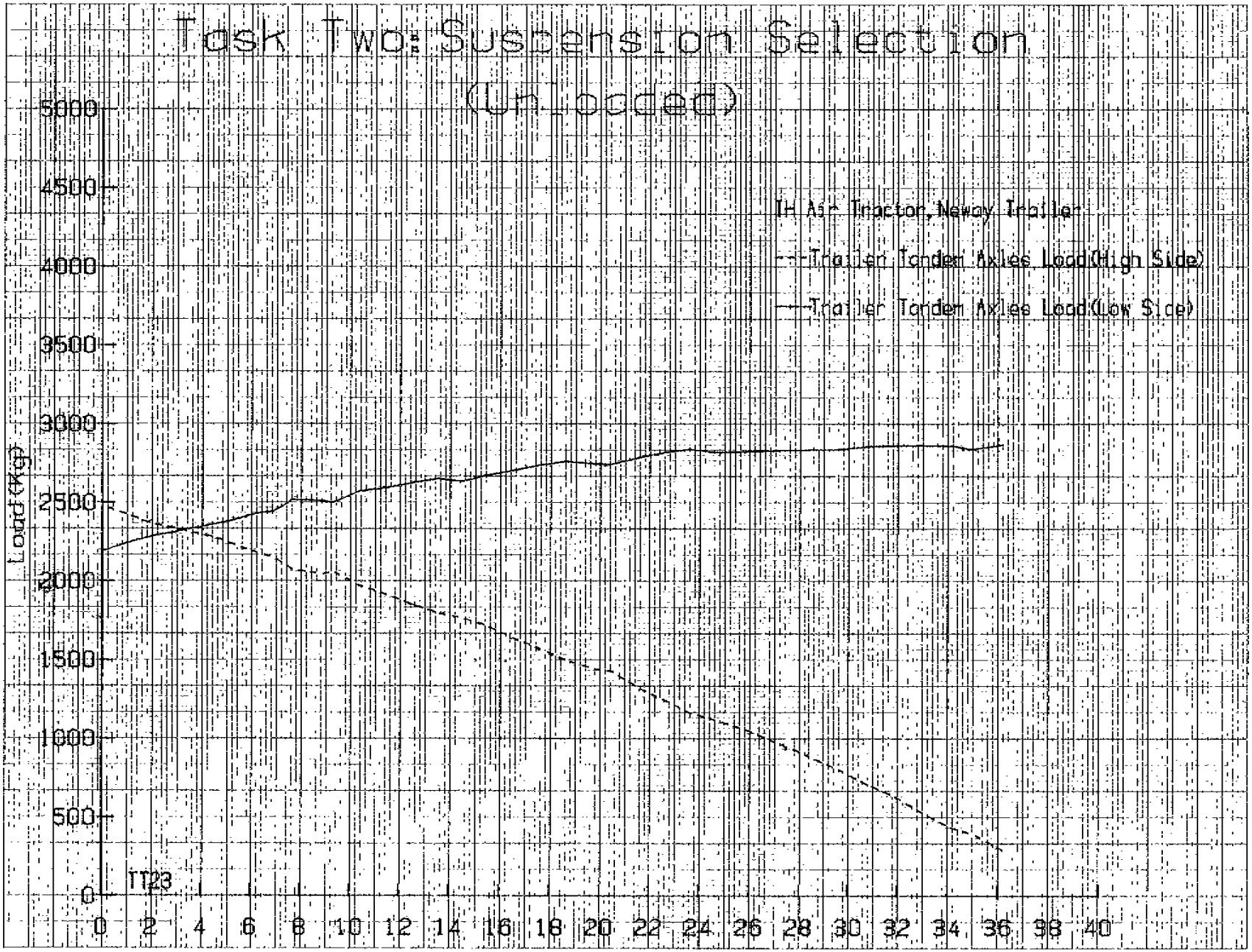
Task Two: Suspension Selection

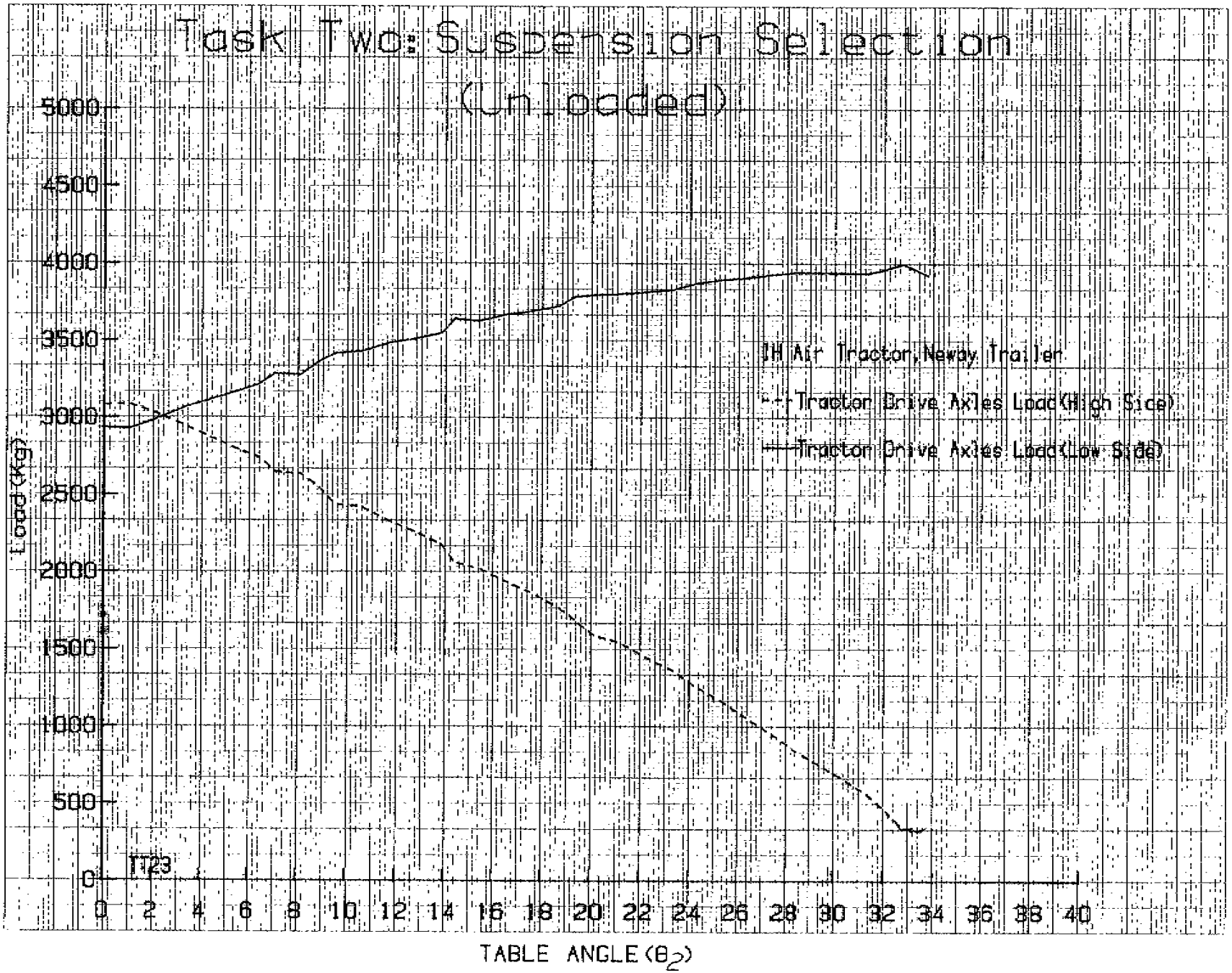
DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
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	IM Air
SUSPENSION TYPE ON TRAILER	Neway AR95
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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,24M
AMBIENT TEMPERATURE	15°c


Task Two: Suspension Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load(Kg)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE(θ1)
IH Air Tractor, Neway Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
127



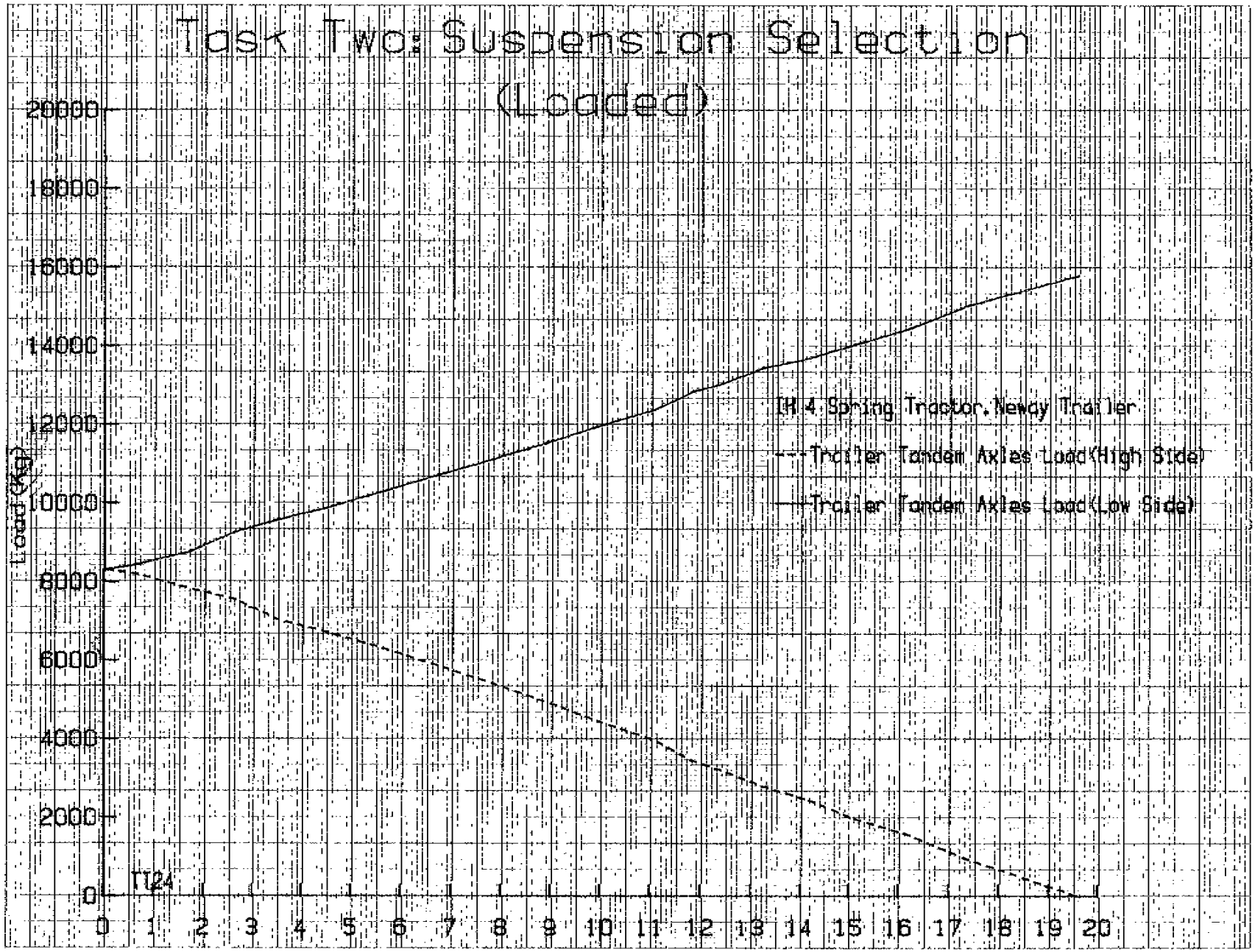


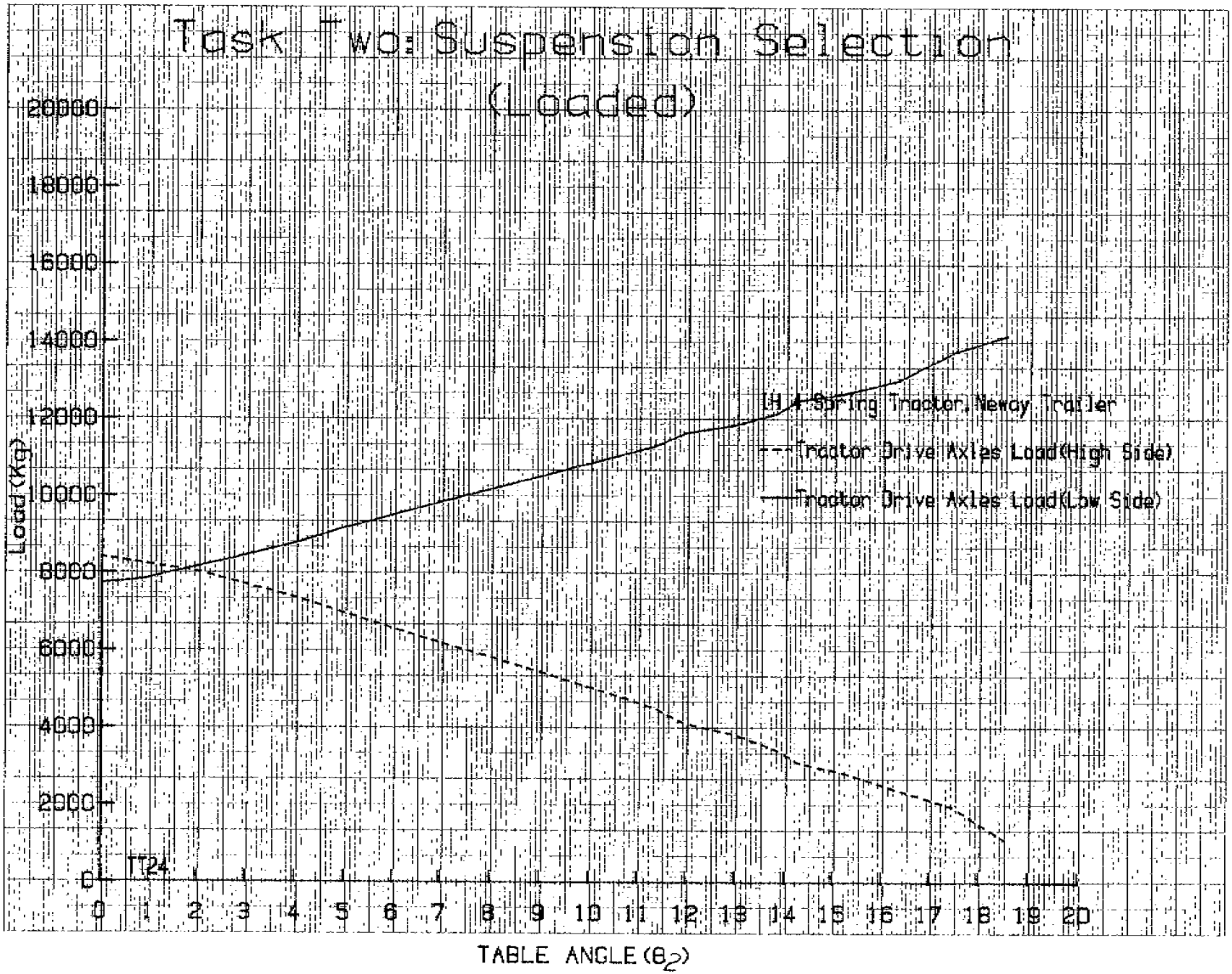

Task Two: Suspension Selection
(Unloaded)
IH Air Tractor, Neway Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load (kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
T123
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ_2)

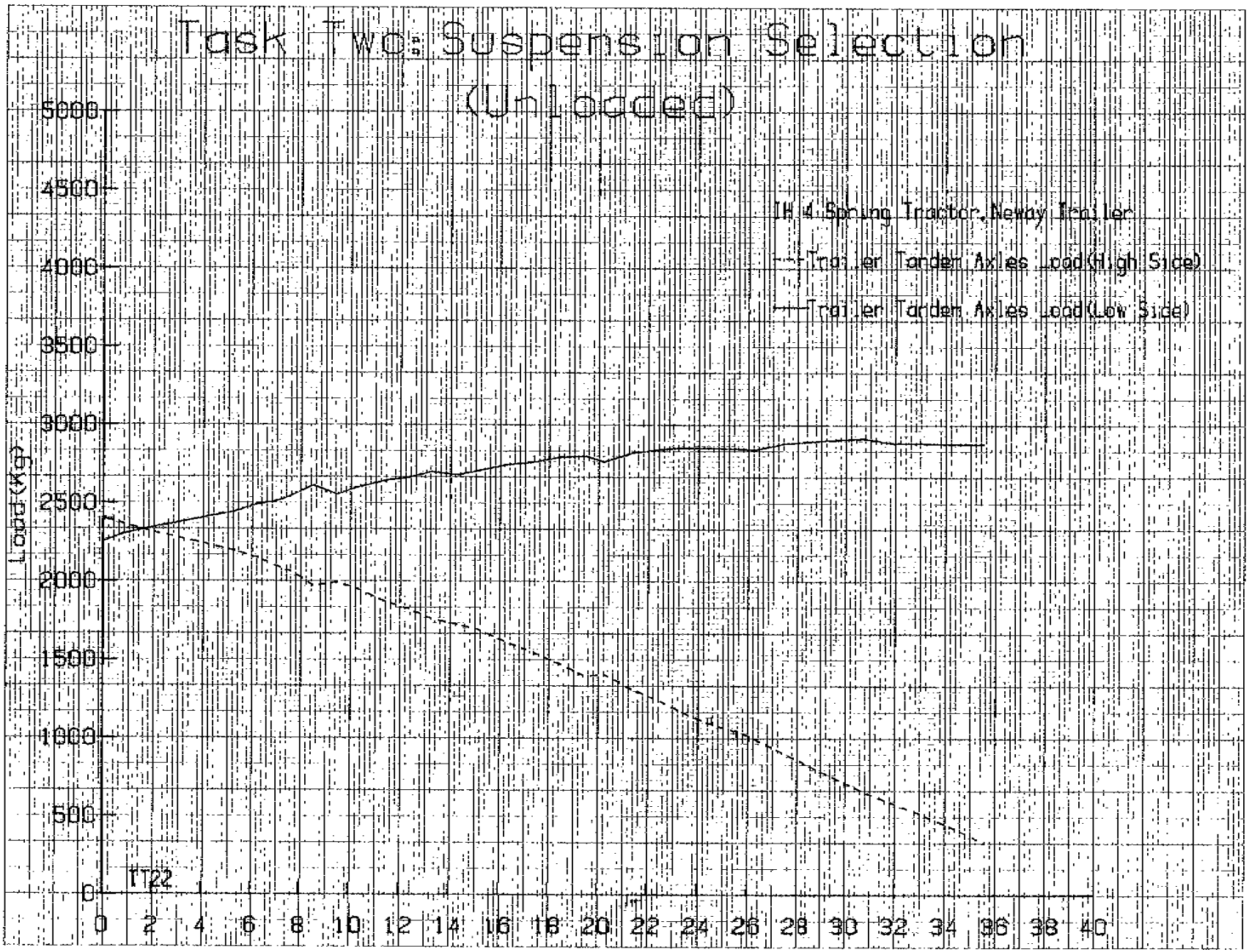
Task Two:Suspension Selection

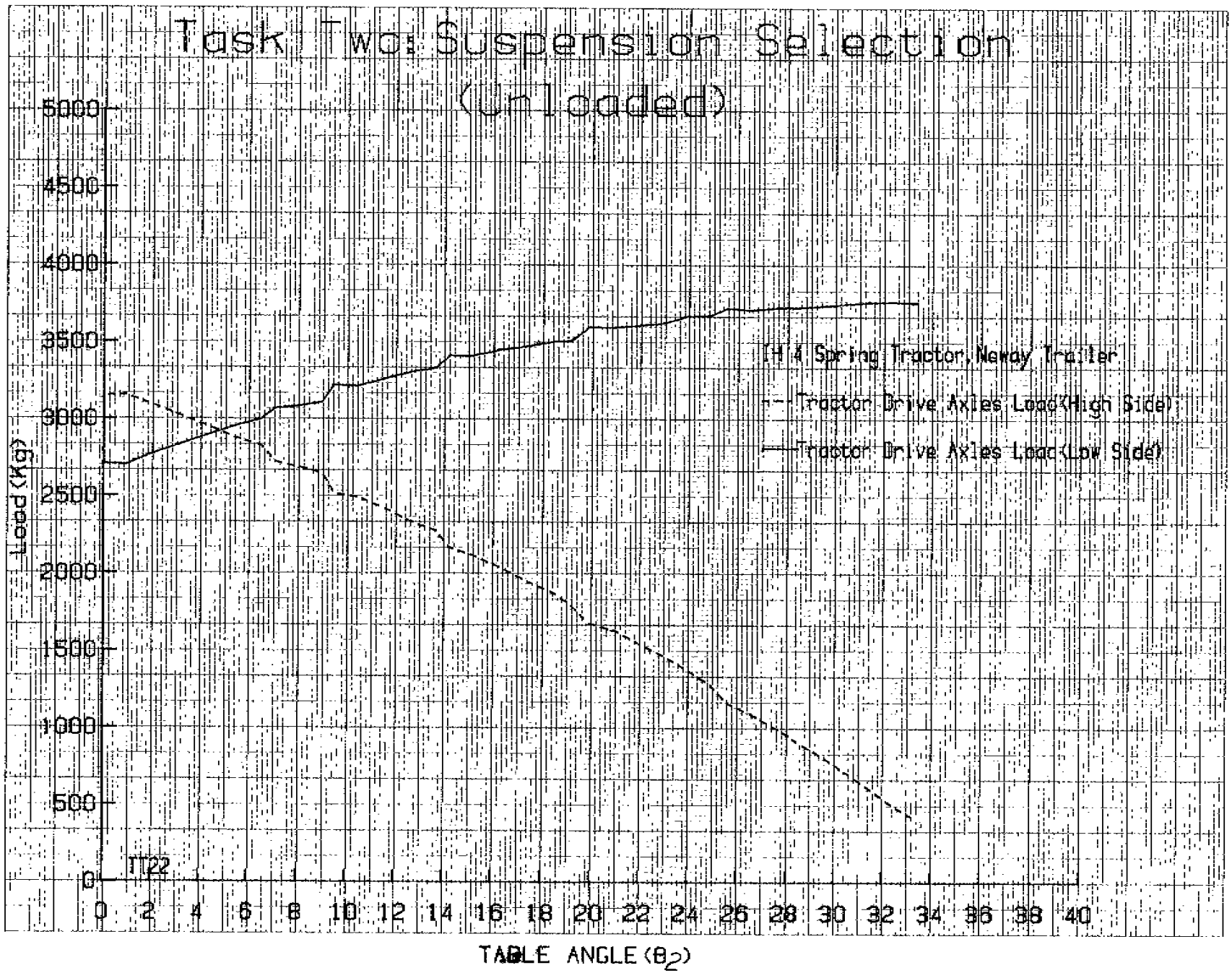
DESCRIPTION

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	IM 4 Springs
SUSPENSION TYPE ON TRAILER	Neway AR95
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c


Task Two: Suspension Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
IH 4 Spring Tractor, Neway Trailer
---Trailer Tandem Axles Load(High Side)
——Trailer Tandem Axles Load(Low Side)
TI24
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ1)


Task Two Suspension Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
TT24
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ_2)
4 Spring Tractor, Neway Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

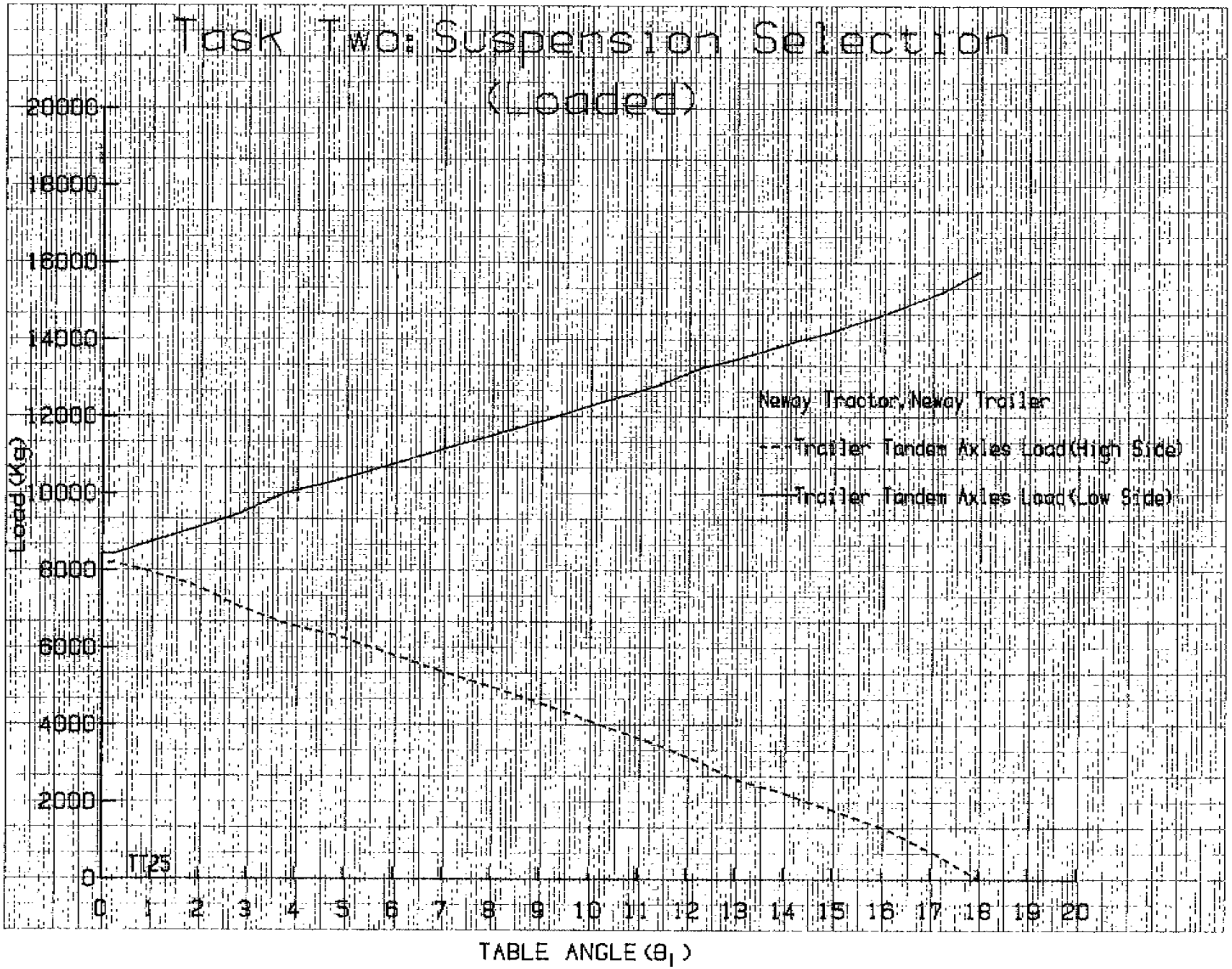

Task Two: Suspension Selection
(Unloaded)
IH 4 Spring Tractor,Neway Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT22
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)

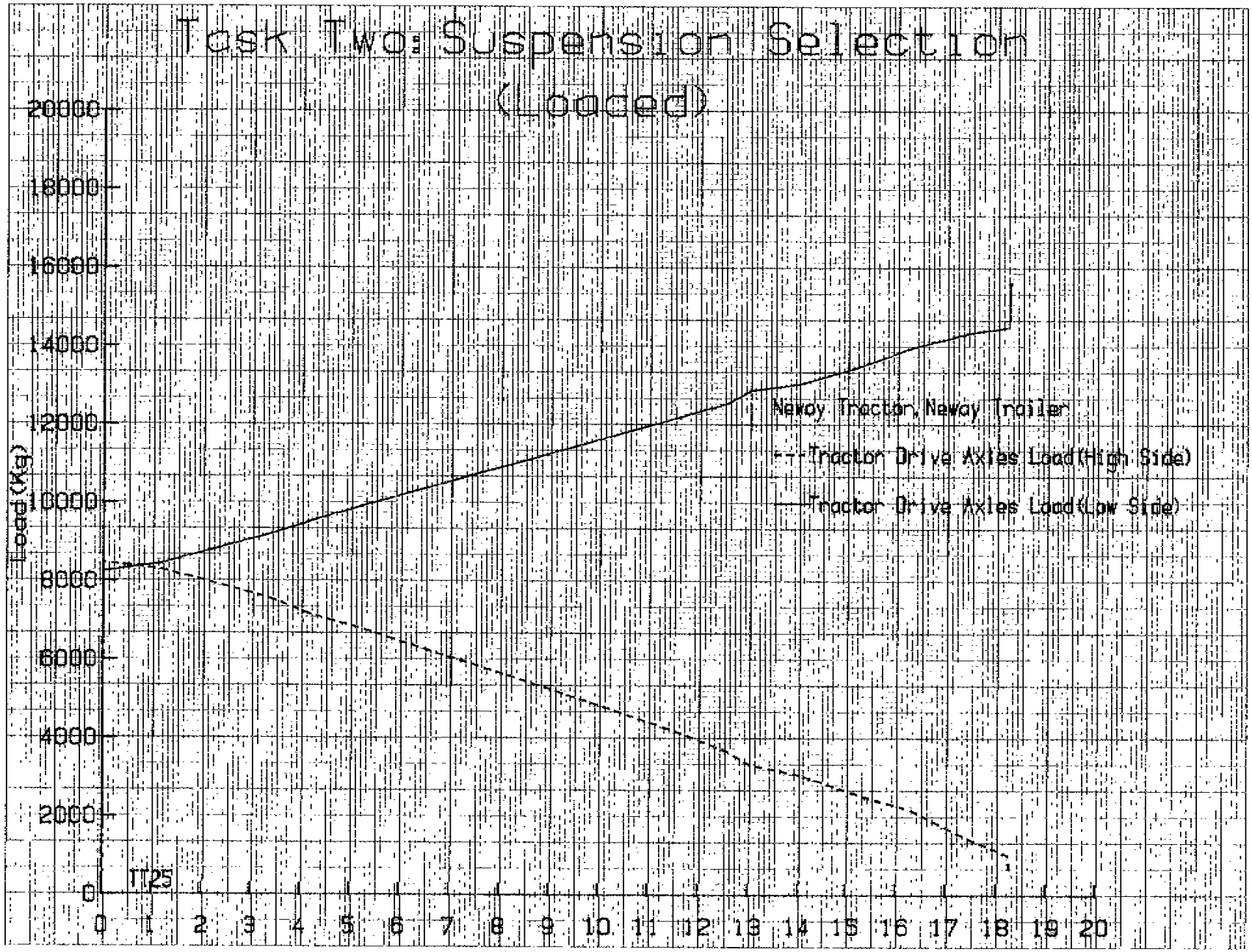

Task Two: Suspension Selection
(Unloaded)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
IT22
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ2)
IH 4 Spring Tractor, Neway Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

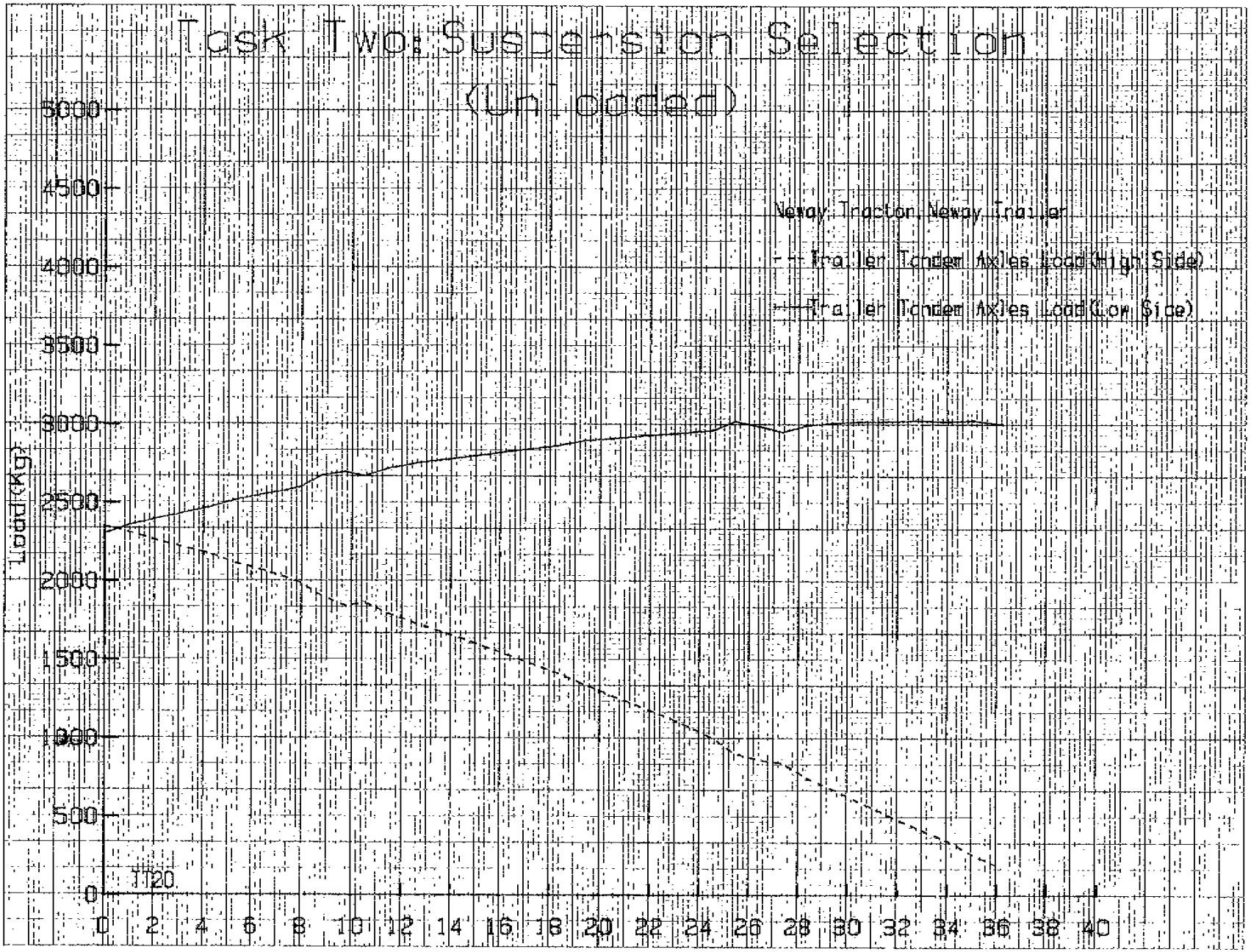
Task Two:Suspension Selection

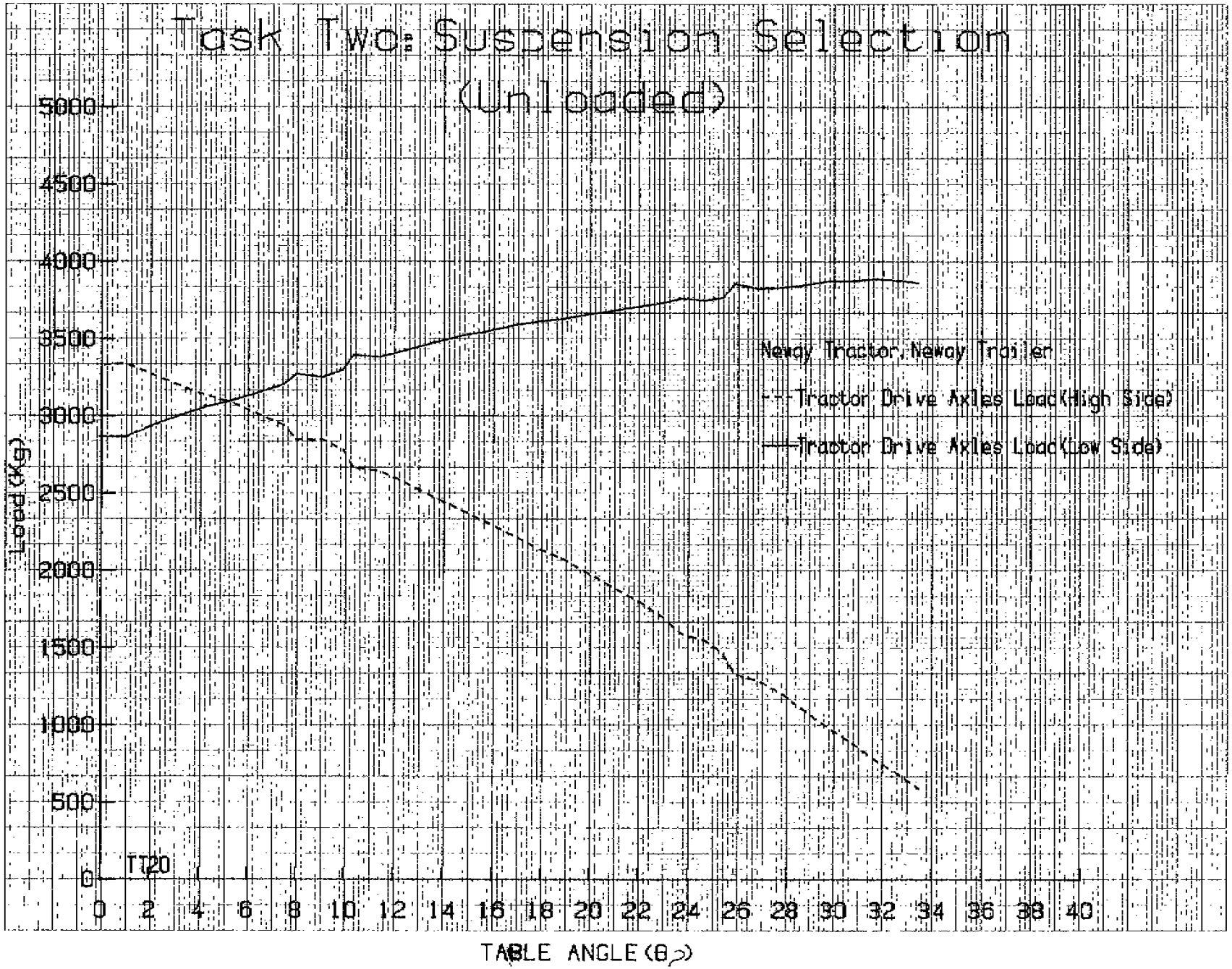
DESCRIPTION

TRACTOR TYPE	Inter F-9370
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 ARD244
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	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,25M
AMBIENT TEMPERATURE	10°c


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ1)
Neway Tractor,Neway Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT25
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Neway Tractor, Neway Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
TABLE ANGLE (θ_2)

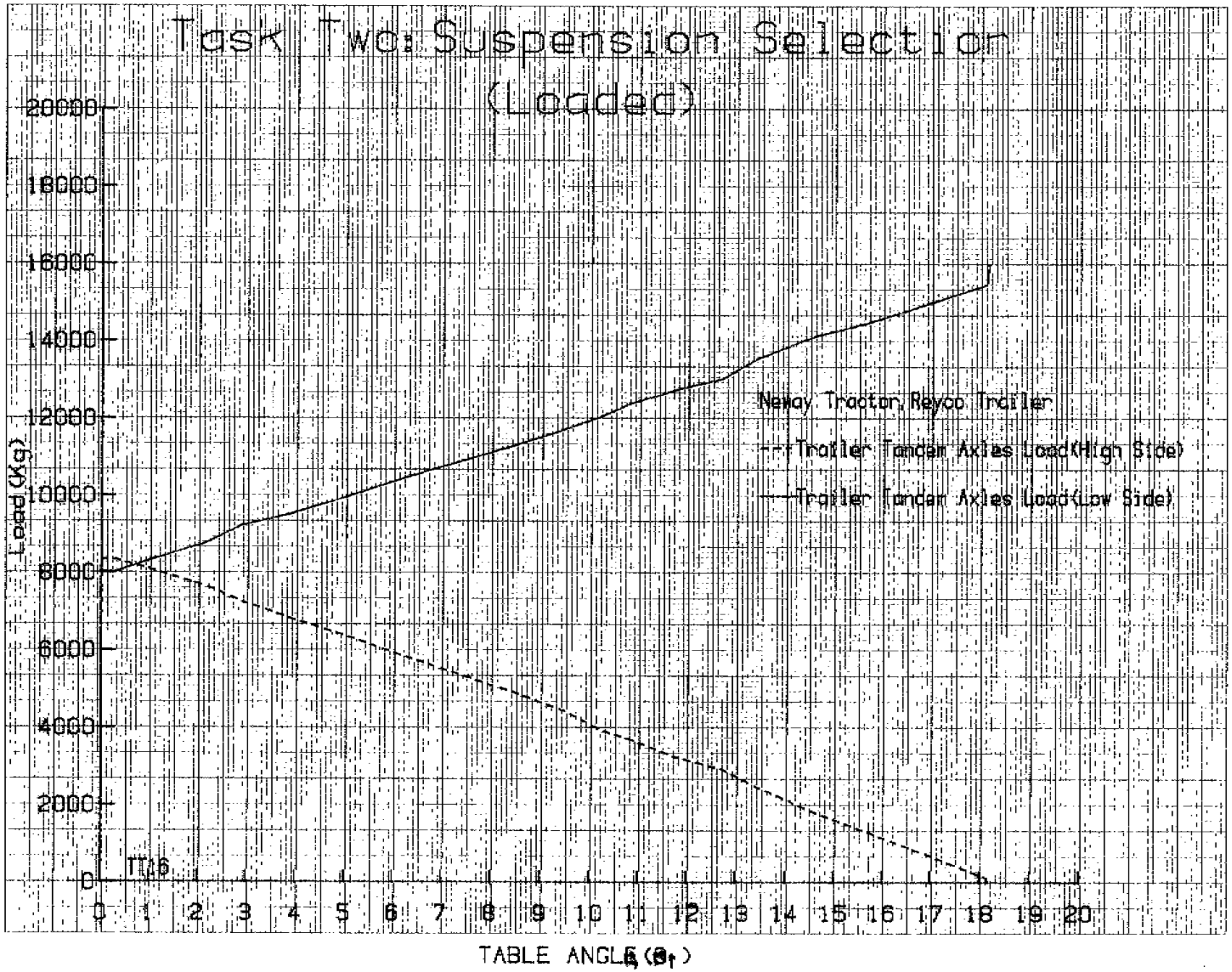

Task Two: Suspension Selection
(unloaded)
Neway Tractor, Neway Trailer
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)
Load (kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT20
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
TABLE ANGLE (θ_1)

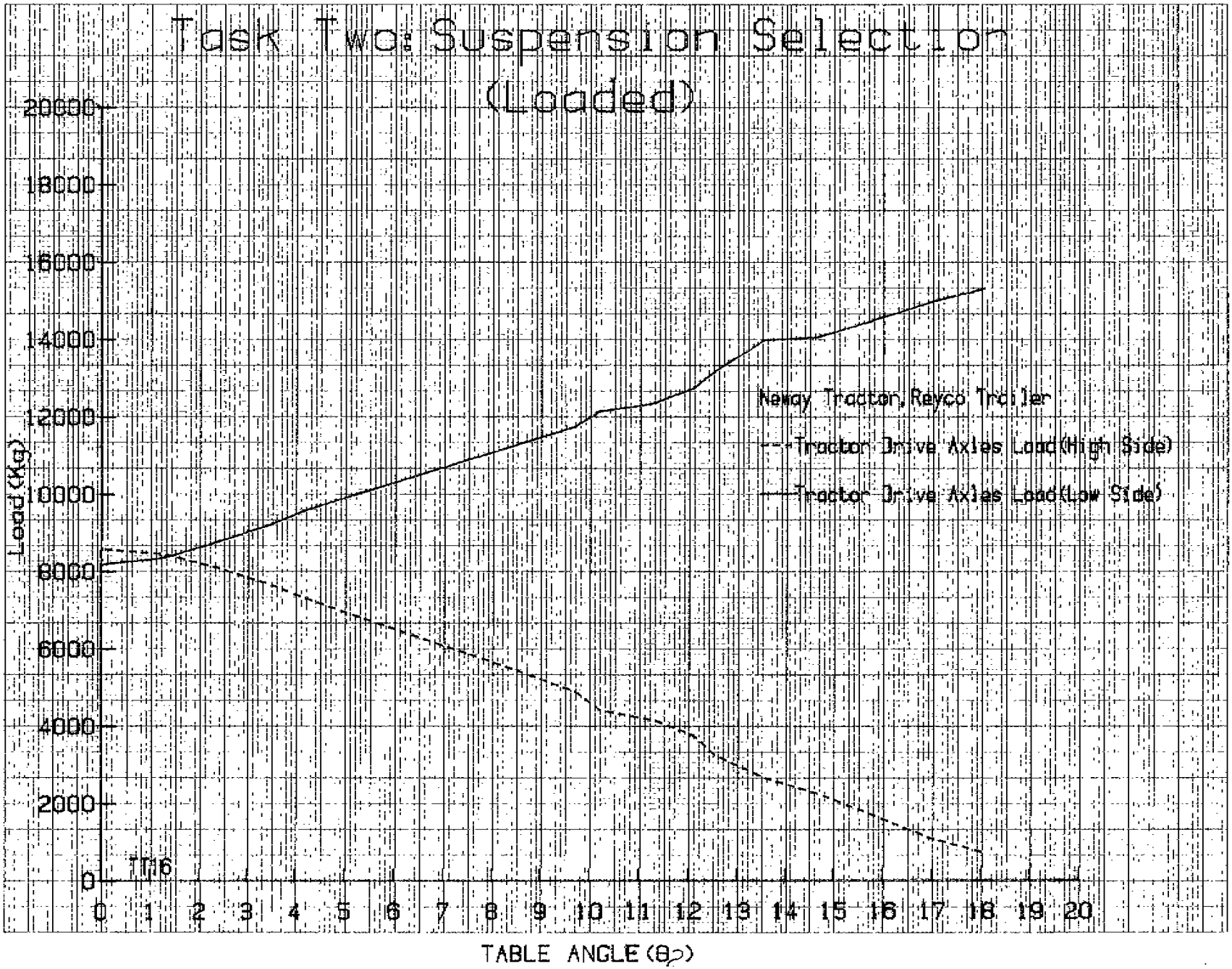

Task Two: Suspension Selection
(Unloaded)
Load (kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT20
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ)
Neway Tractor, Neway Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

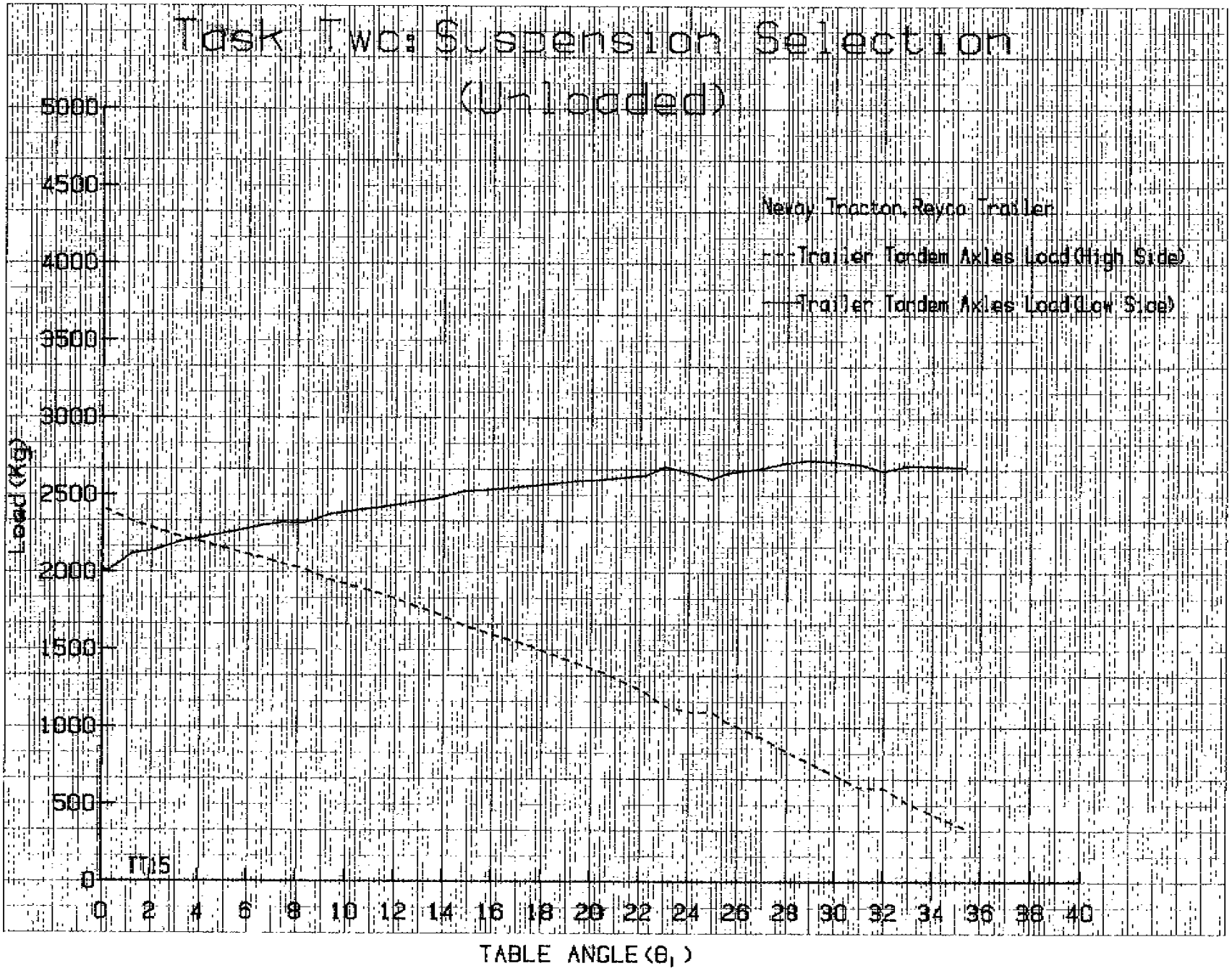
Task Two:Suspension Selection

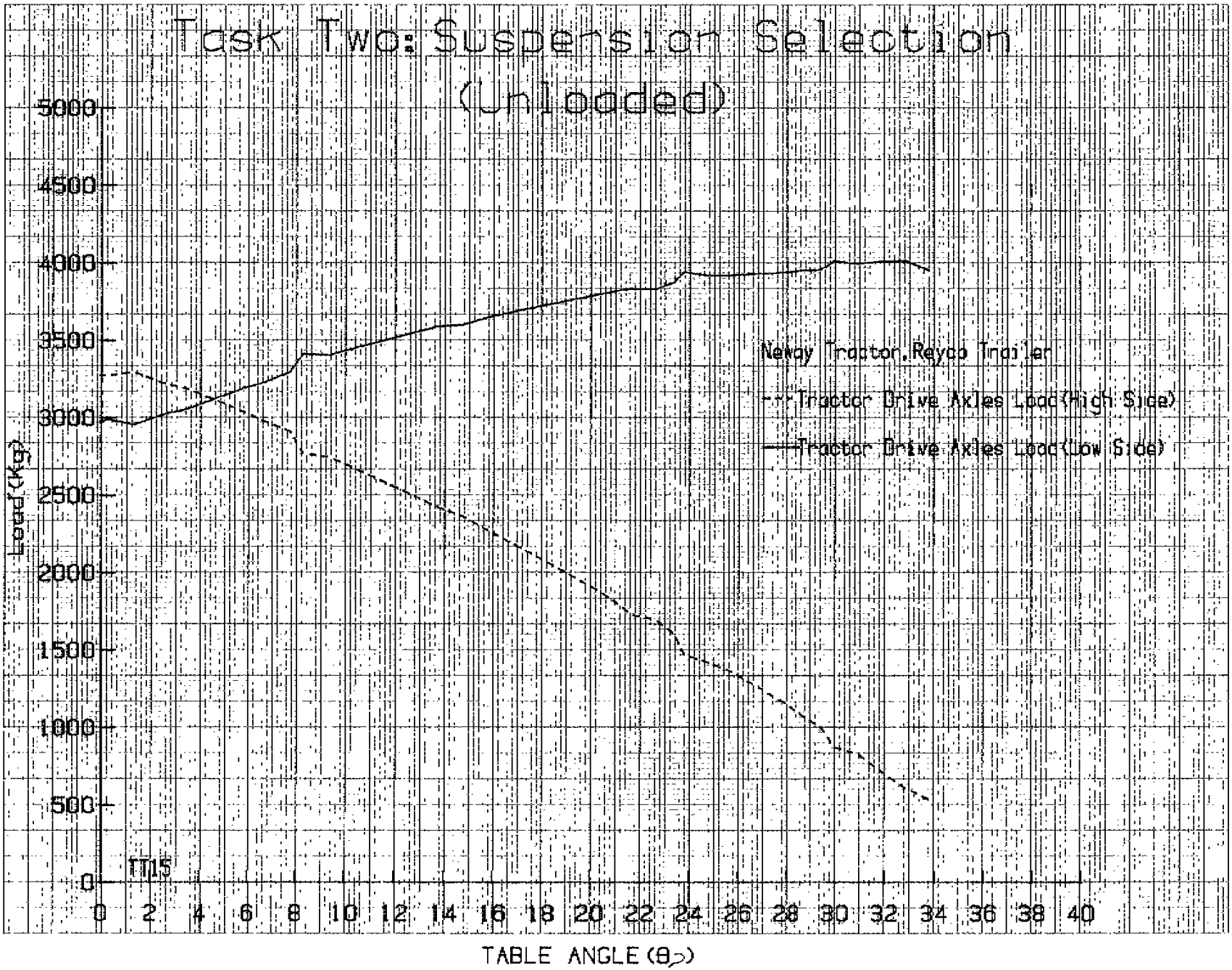
DESCRIPTION

TRACTOR TYPE	Inter F-9370
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 ARD 244
SUSPENSION TYPE ON TRAILER	Reyco 21D
AXLE SPREAD ON TRACTOR	4,85M 1,35M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,40M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,25M
AMBIENT TEMPERATURE	10°C


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT26
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θt)
Neway Tractor Reyco Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TM6
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ)
Neway Tractor, Reyco Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

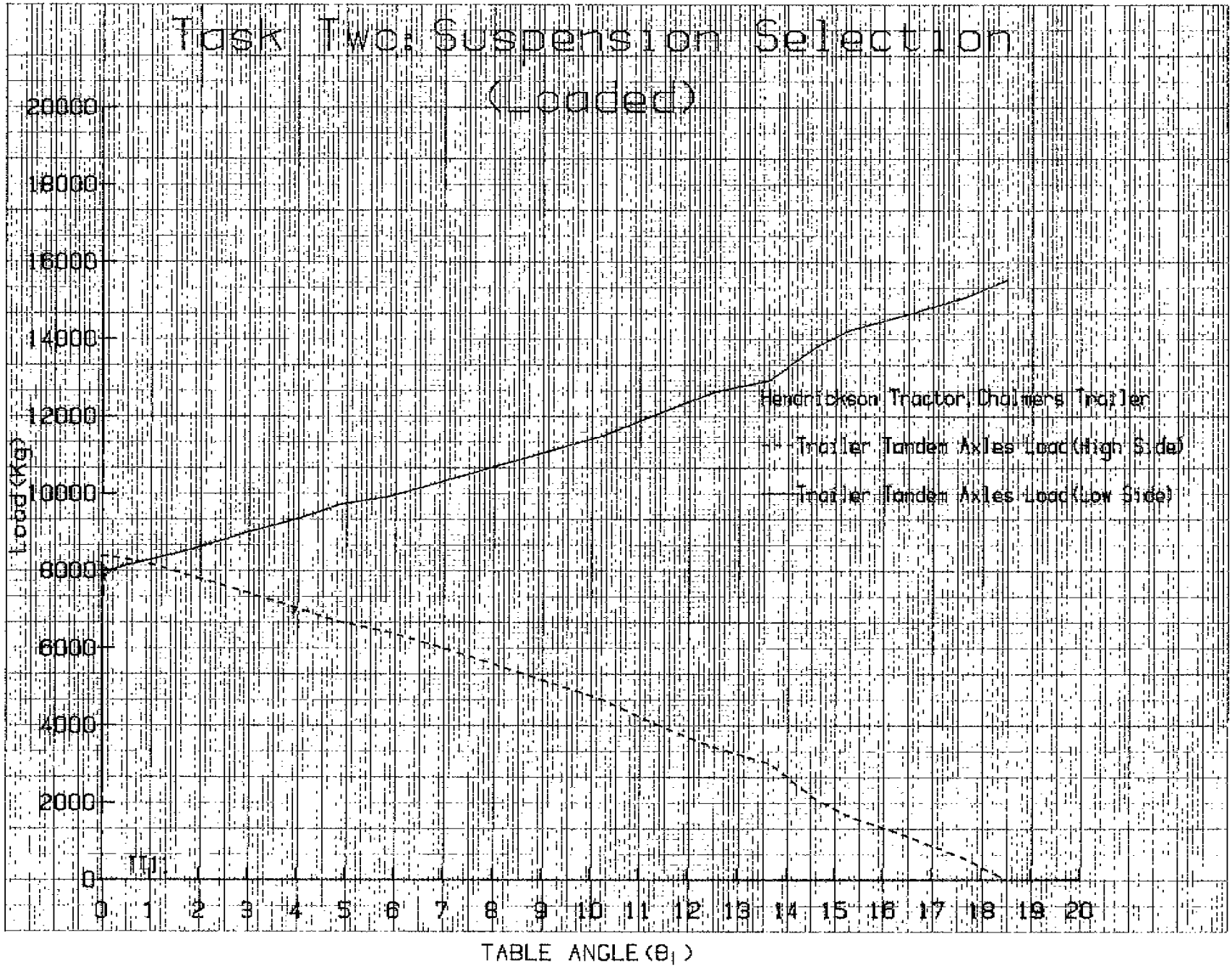

Task Two: Suspension Selection
(Unloaded)
Navay Tractor, Reyco Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load (KG)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT5
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)

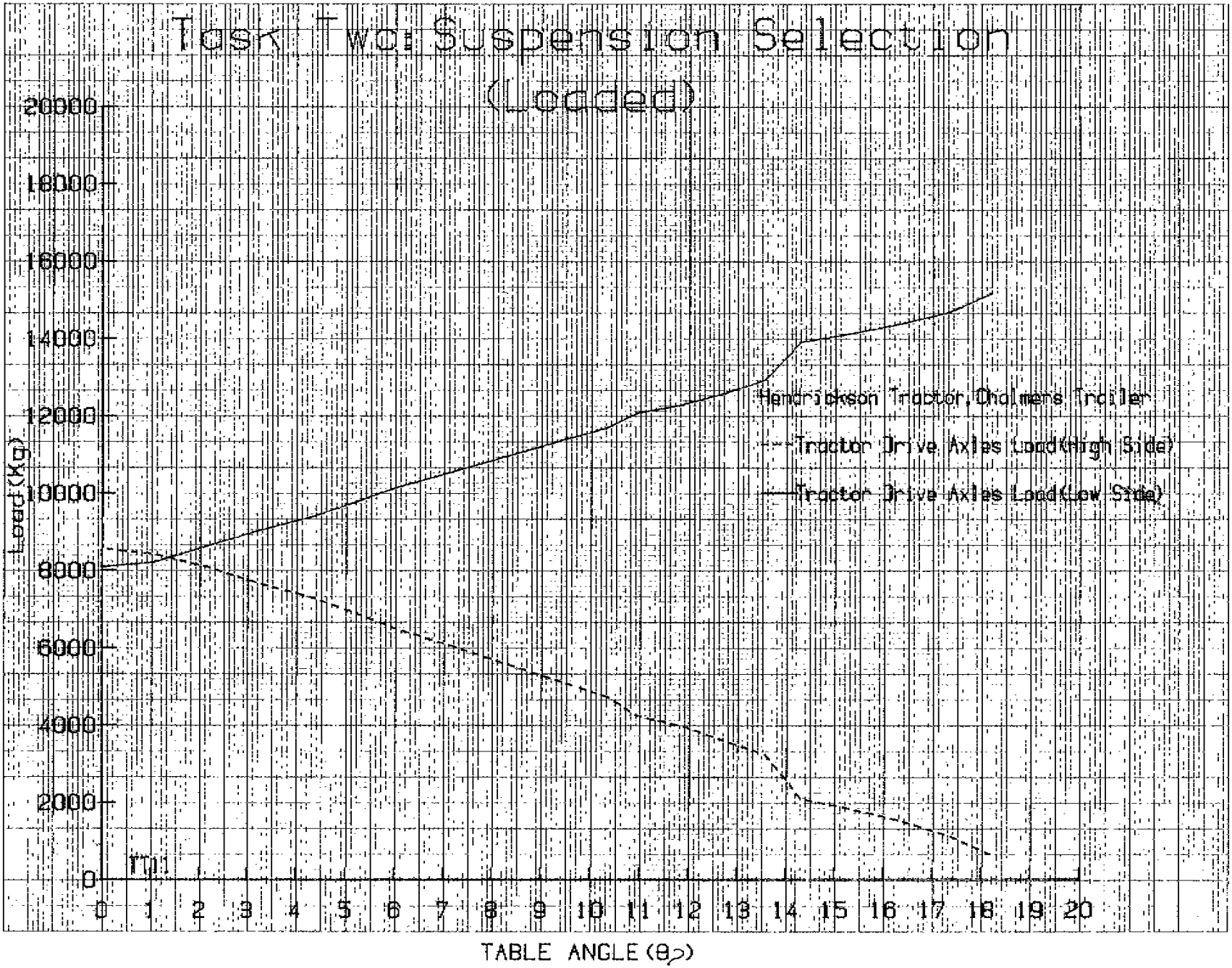

Task Two: Suspension Selection
(unloaded)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ)
Neway Tractor,Reyco Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

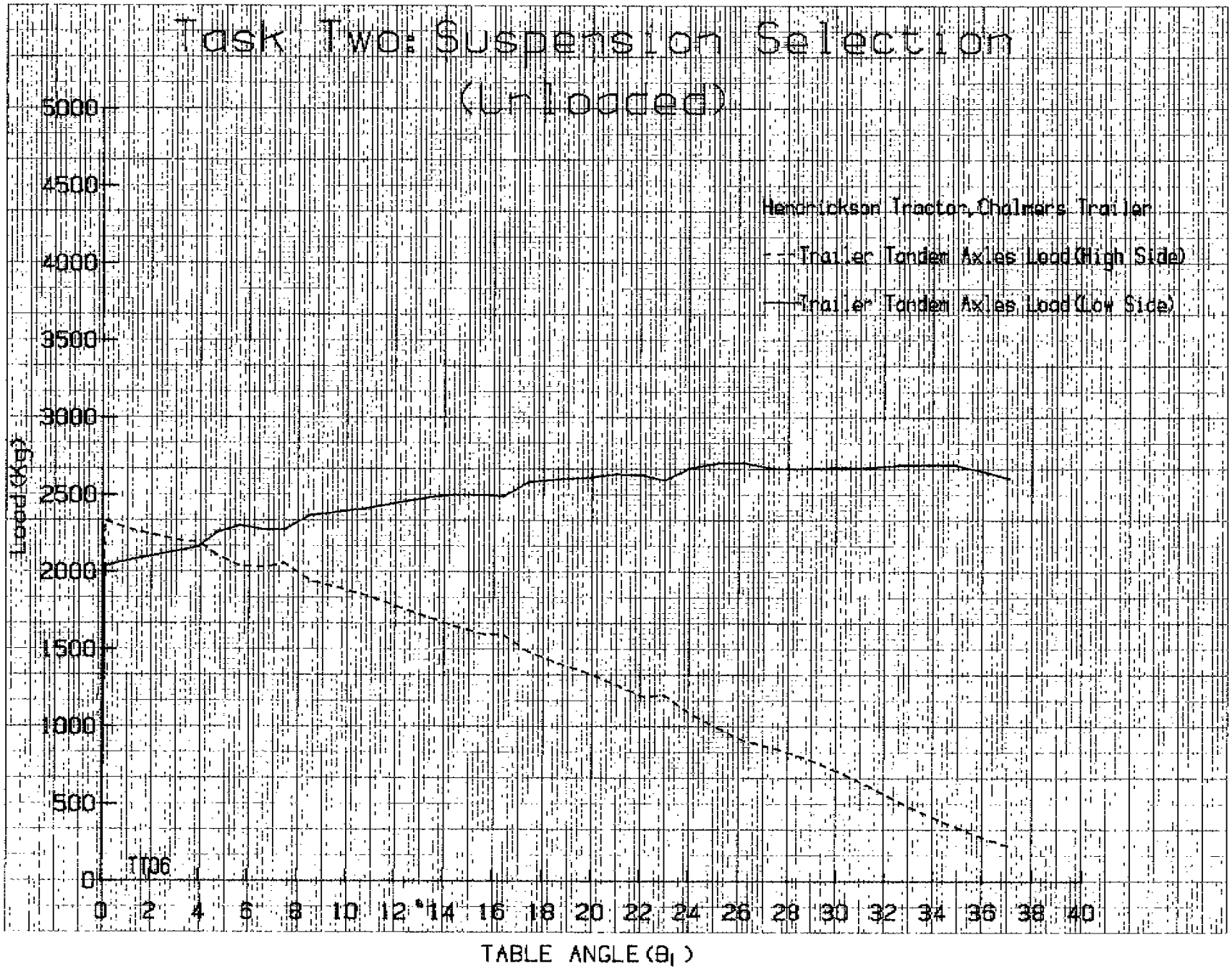
Task Two:Suspension Selection

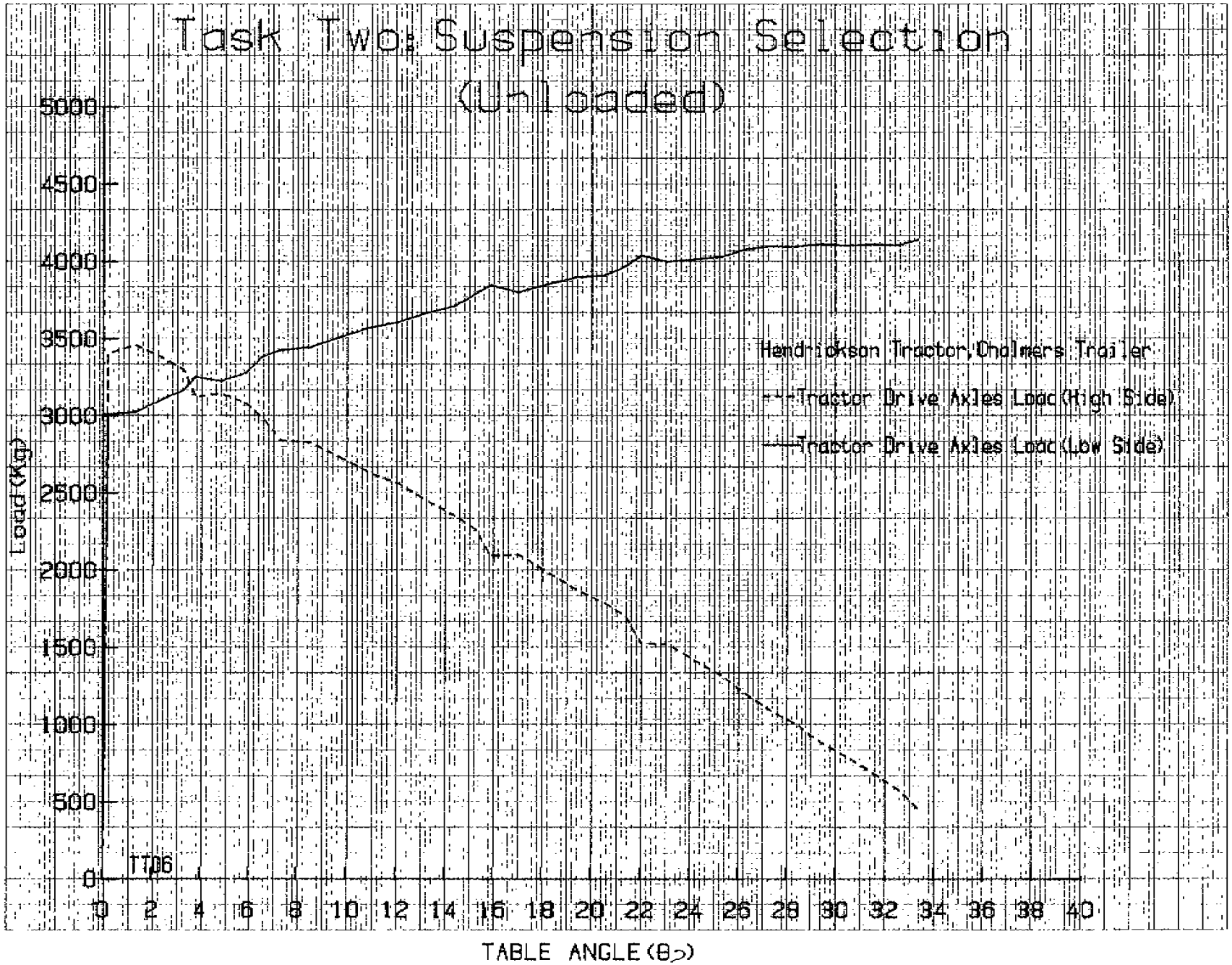
DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	8,02M
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	Hendrickson RTE 440
SUSPENSION TYPE ON TRAILER	Chalmers 700
AXLE SPREAD ON TRACTOR	5,10M 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
HEIGTH OF THE FIFTH WHEEL	1,21M
AMBIENT TEMPERATURE	5°c


Task Two: Suspension Selection
(Loaded)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ_1)
Hendrickson Tractor,Chalmers Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)


Task Two Suspension Selection
(Loaded)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ)
Hendrickson Tractor,Chalmers Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

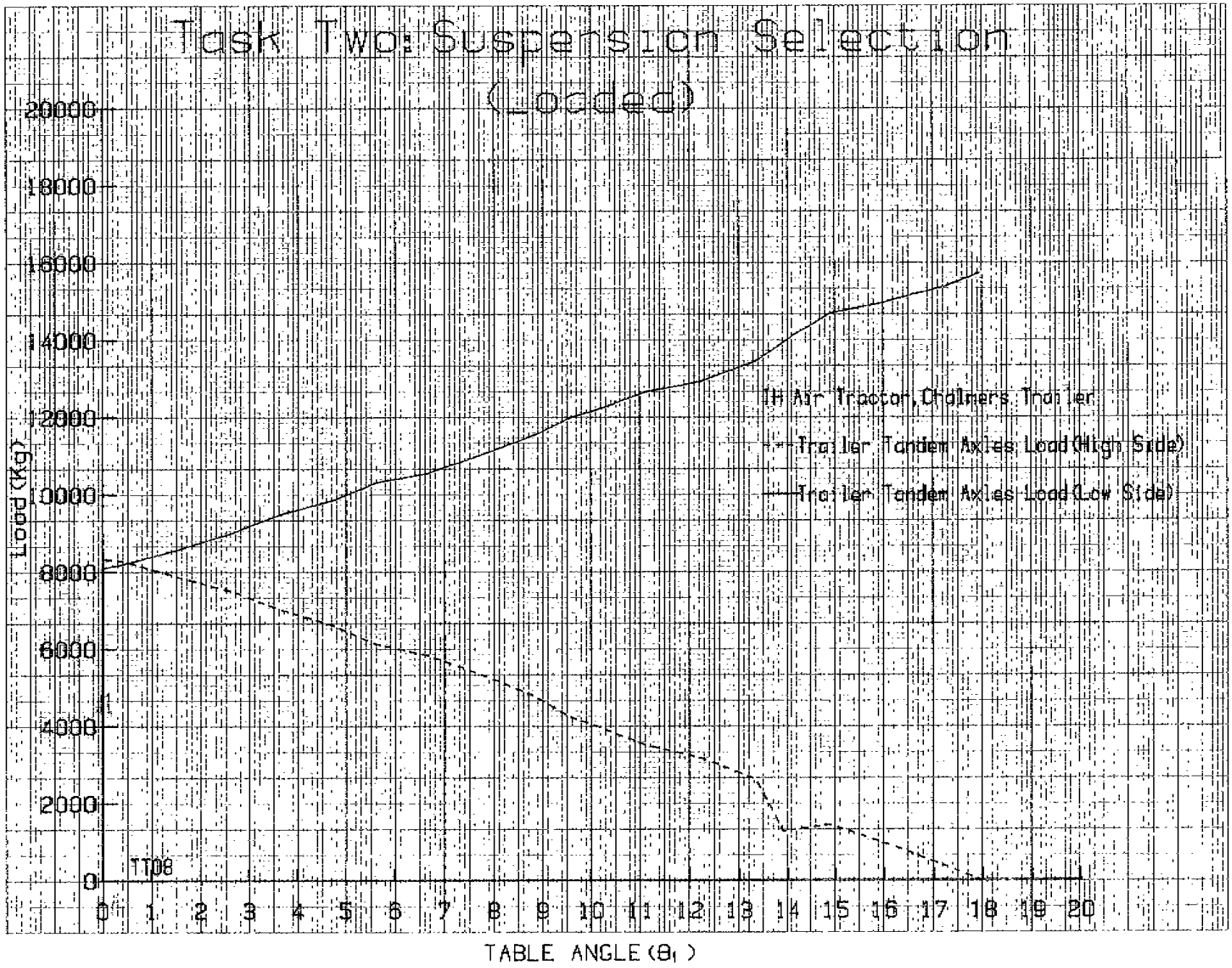

Task Two: Suspension Selection
(Unloaded)
Hendrickson Tractor,Chalmers Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TOP
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)

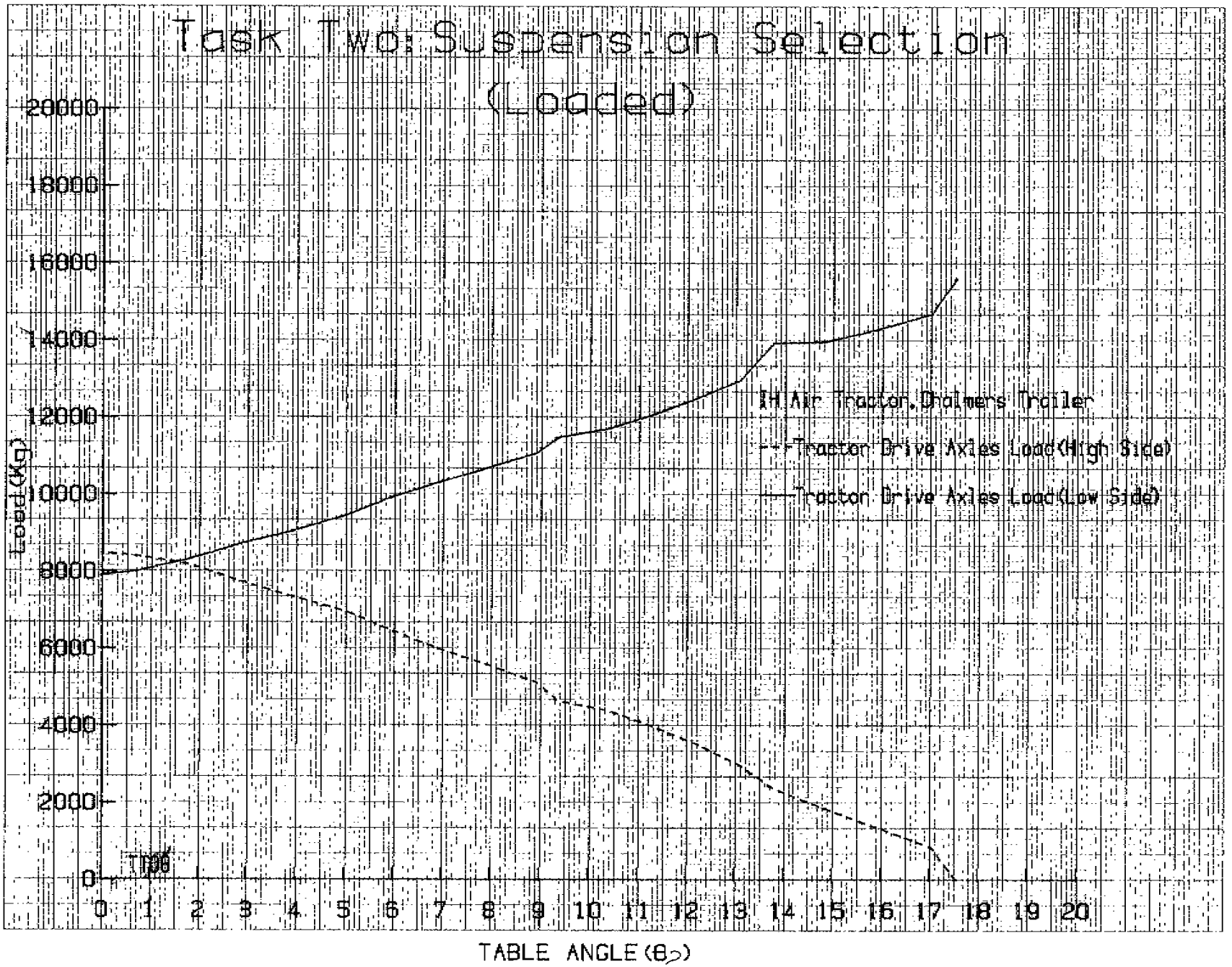


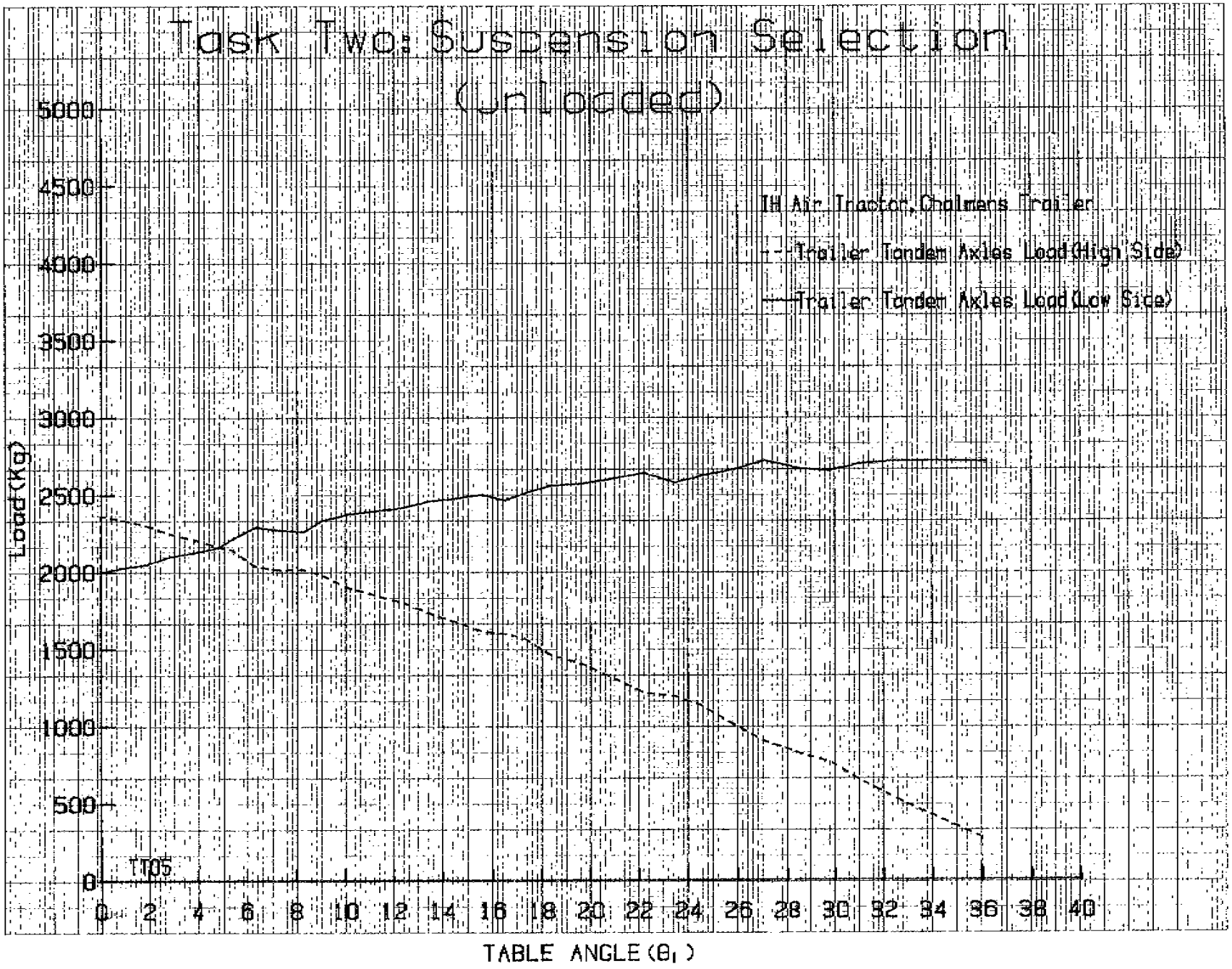
Task Two: Suspension Selection

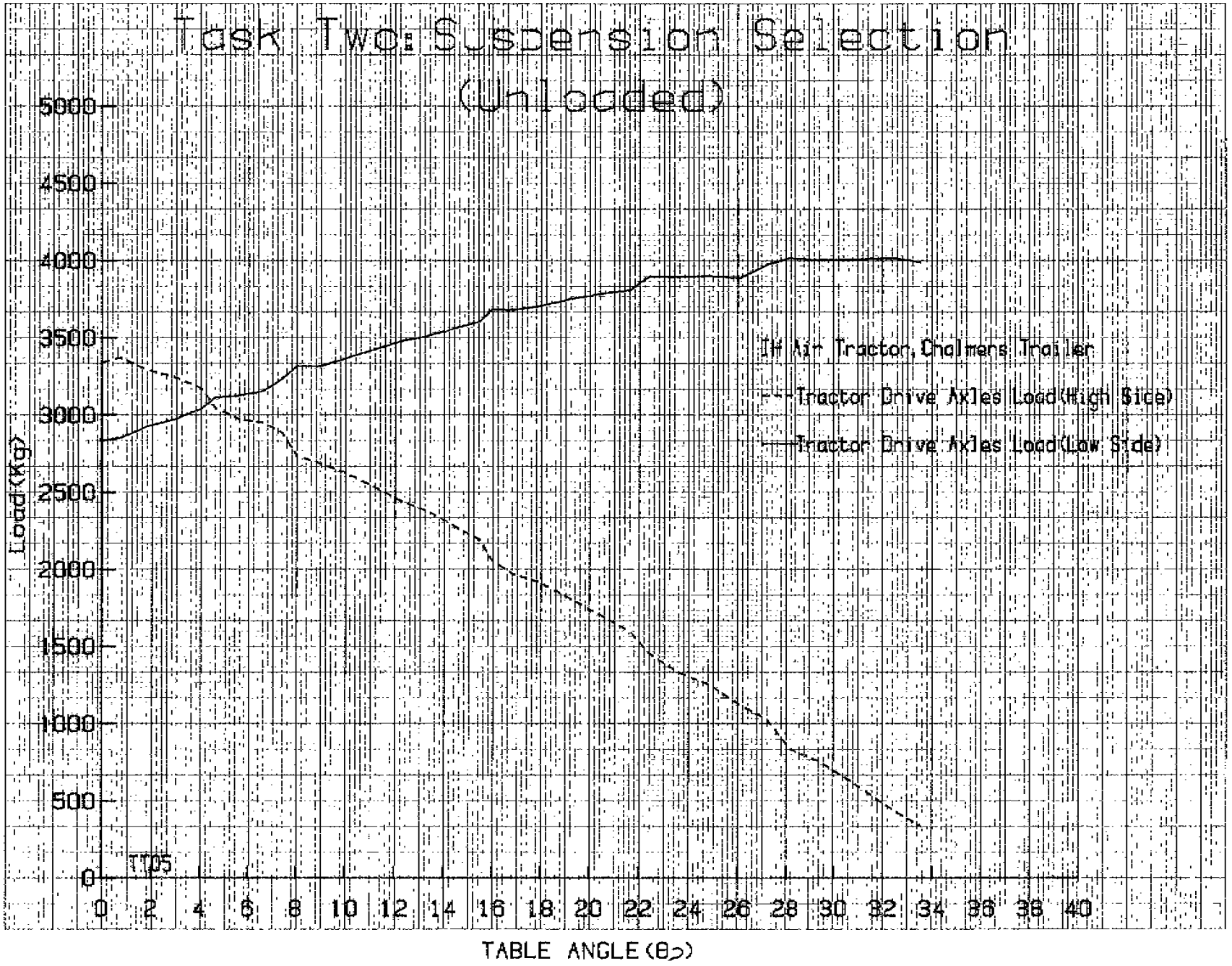
DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,76M Flat Bed
TRACTOR LENGTH	7,57M
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 Air
SUSPENSION TYPE ON TRAILER	Chalmers 700
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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,21M
AMBIENT TEMPERATURE	5°c


Task Two: Suspension Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
TT08
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ1)
IH Air Tractor, Chalmers Trailer
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)



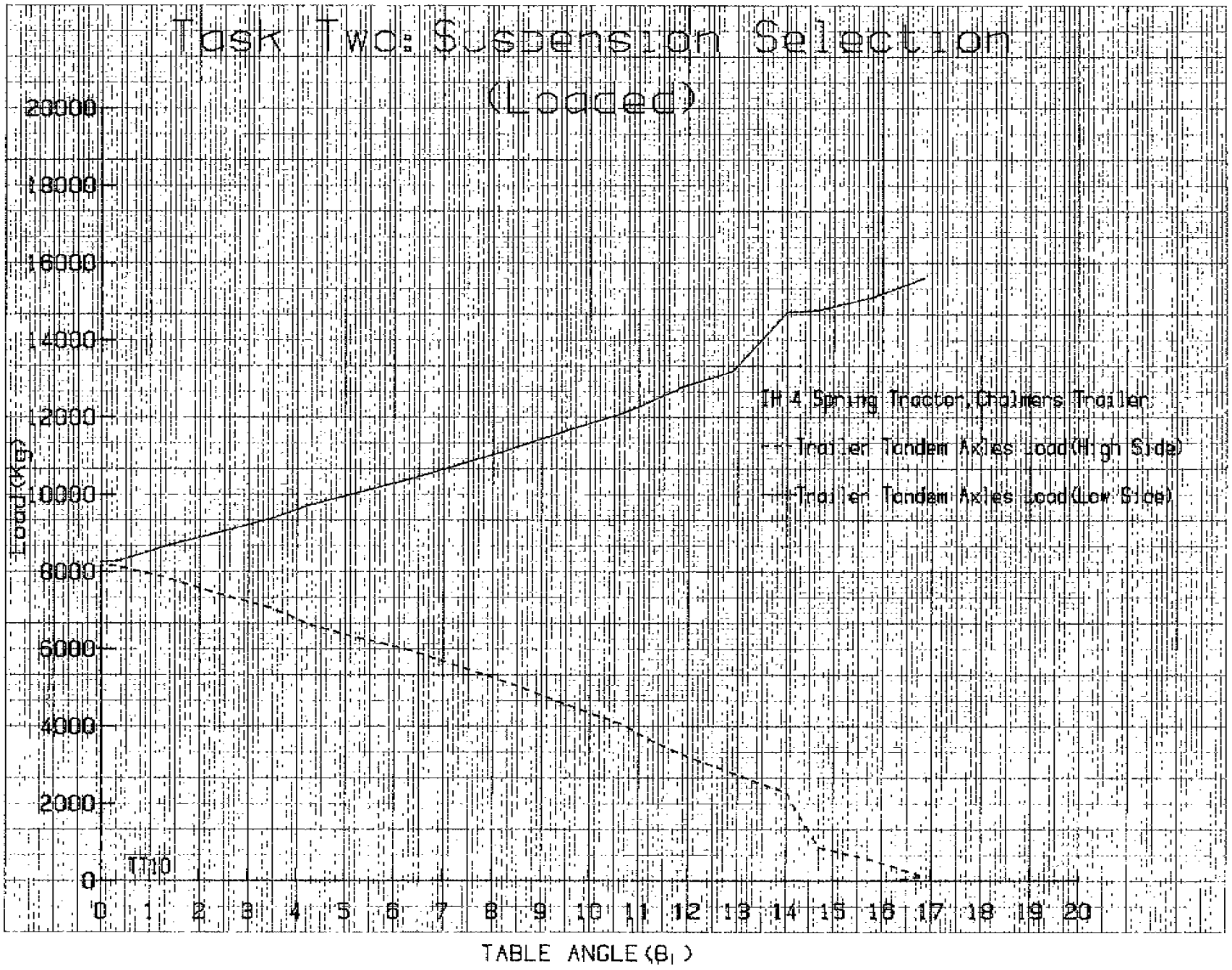


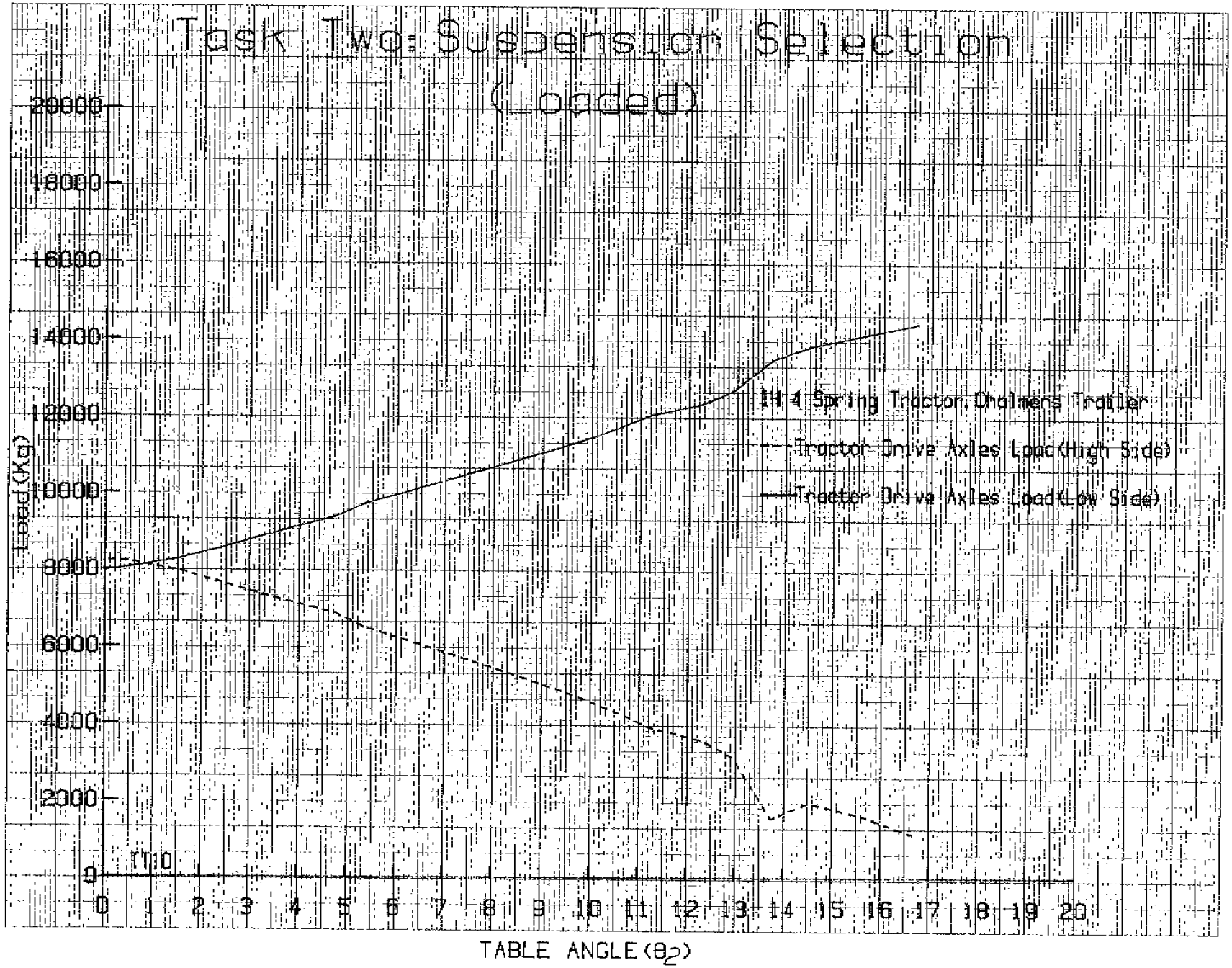

Task Two: Suspension Selection
(Unloaded)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Load (Kg)
TTDS
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ)
1# Air Tractor, Chalmers Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

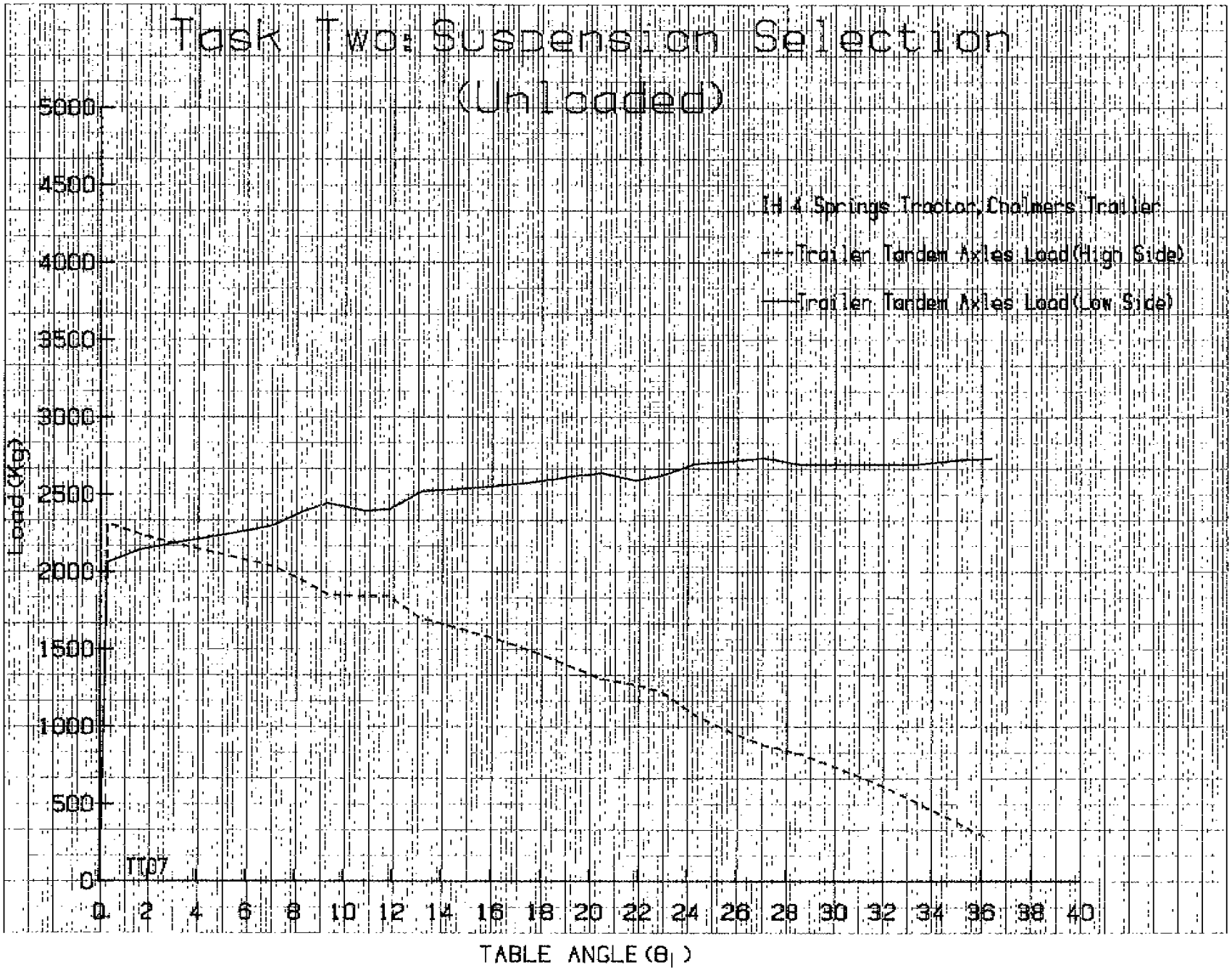
Task Two: Suspension Selection

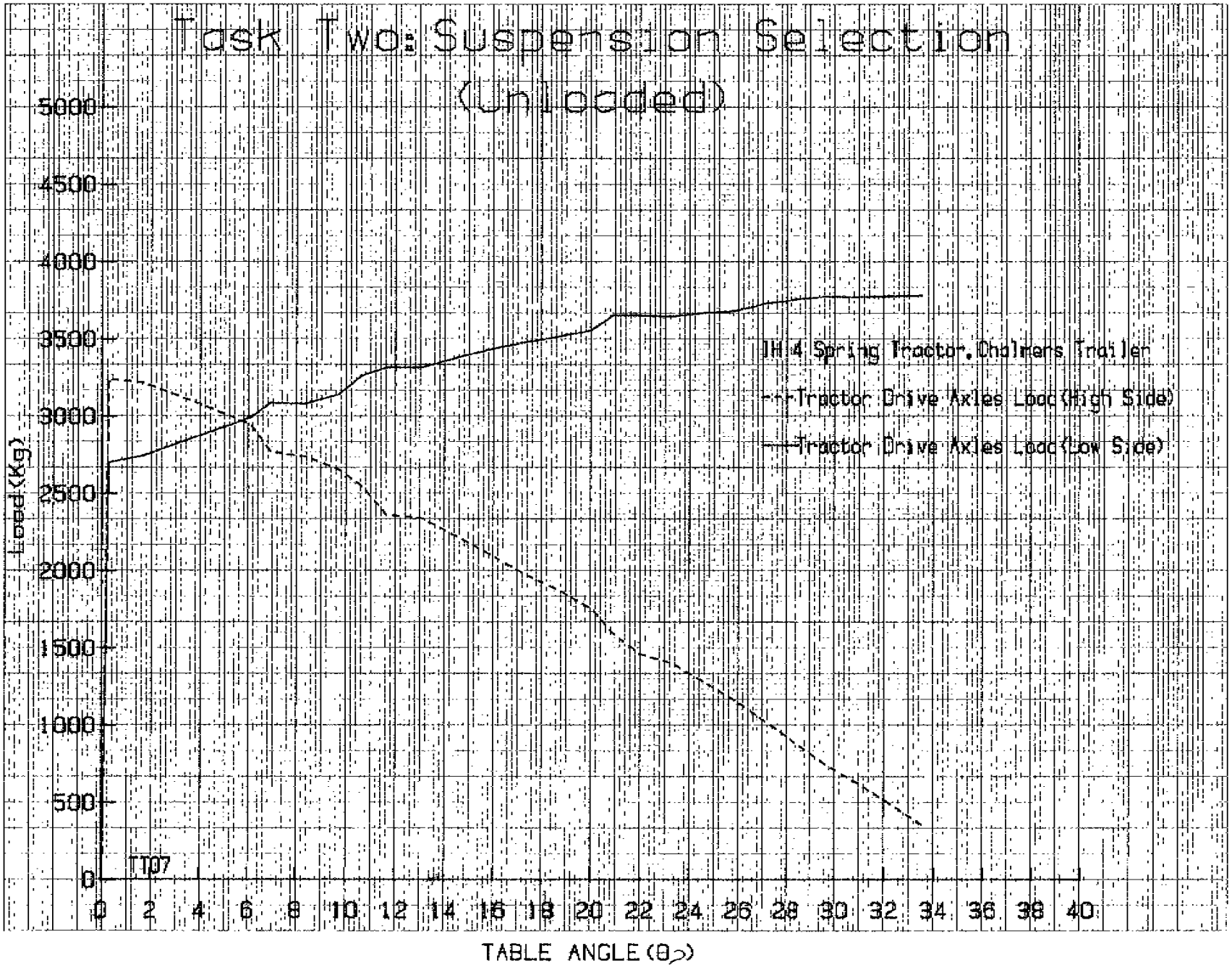
DESCRIPTION

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	1H 4 Springs
SUSPENSION TYPE ON TRAILER	Chalmers 700
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,38M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	0 c


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
5000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ1)
IH 4 Spring Tractor, Chalmers Trailer
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ2)
IH 4 Spring Tractor, Chalmers Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

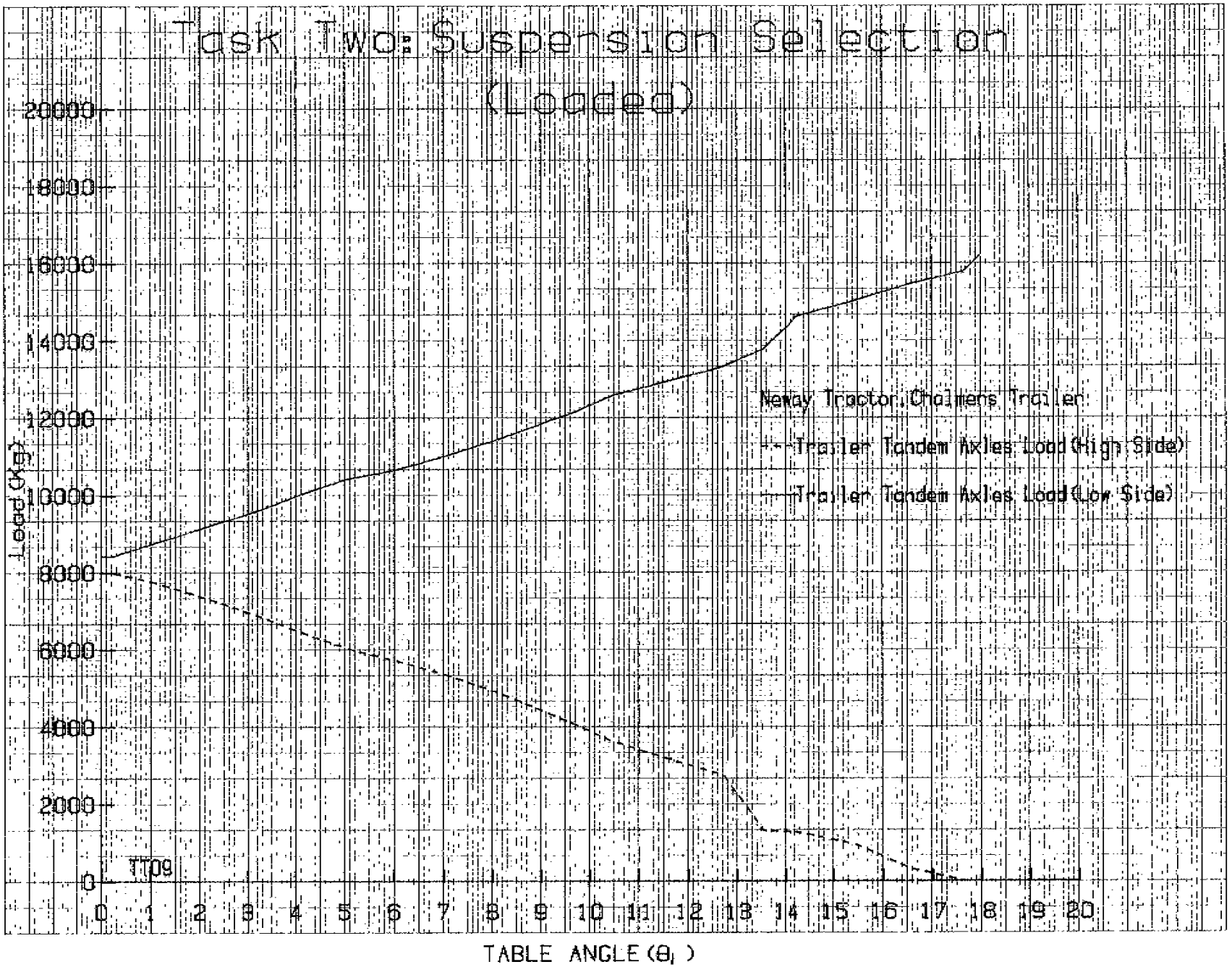

Task Two: Suspension Selection
(Unloaded)
IH 4 Springs Tractor,Chalmers Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT07
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ|)

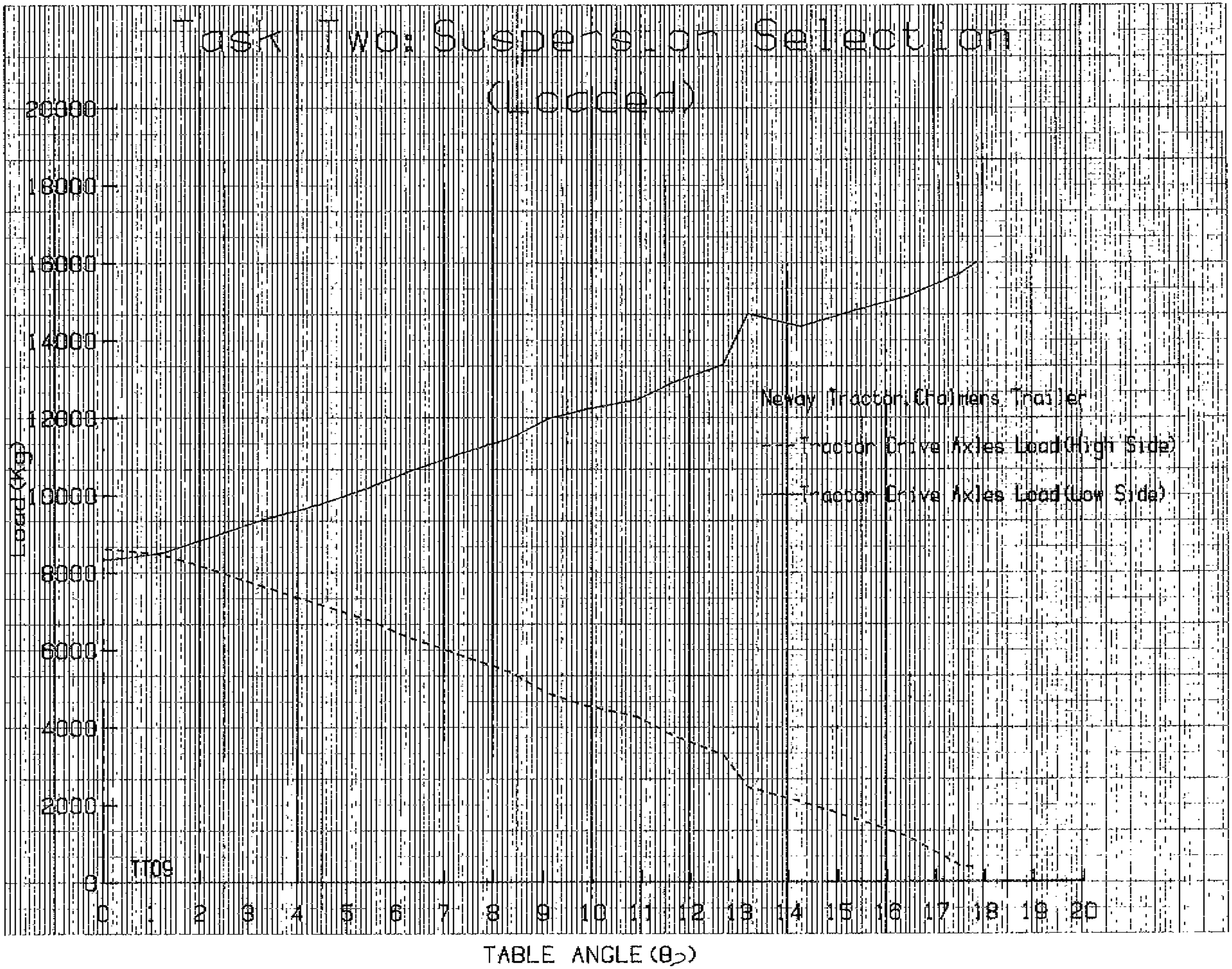

Task Two: Suspension Selection
(Unloaded)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TTp7
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ)
JH 4 Spring Tractor.Chalmers Trailer
Tractor Drive Axles Load (High Side)
Tractor Drive Axles Load (Low Side)

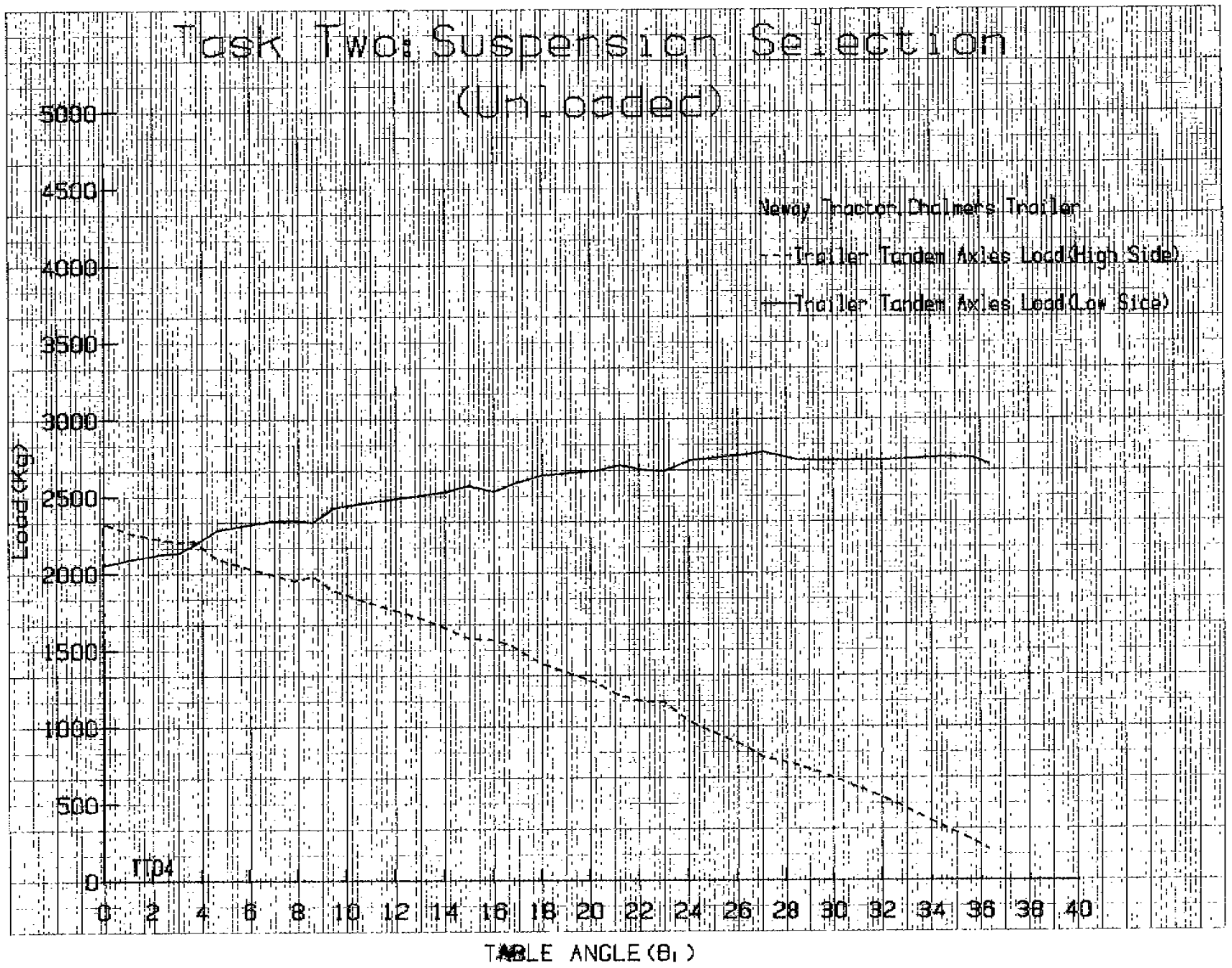
Task Two:Suspension Selection

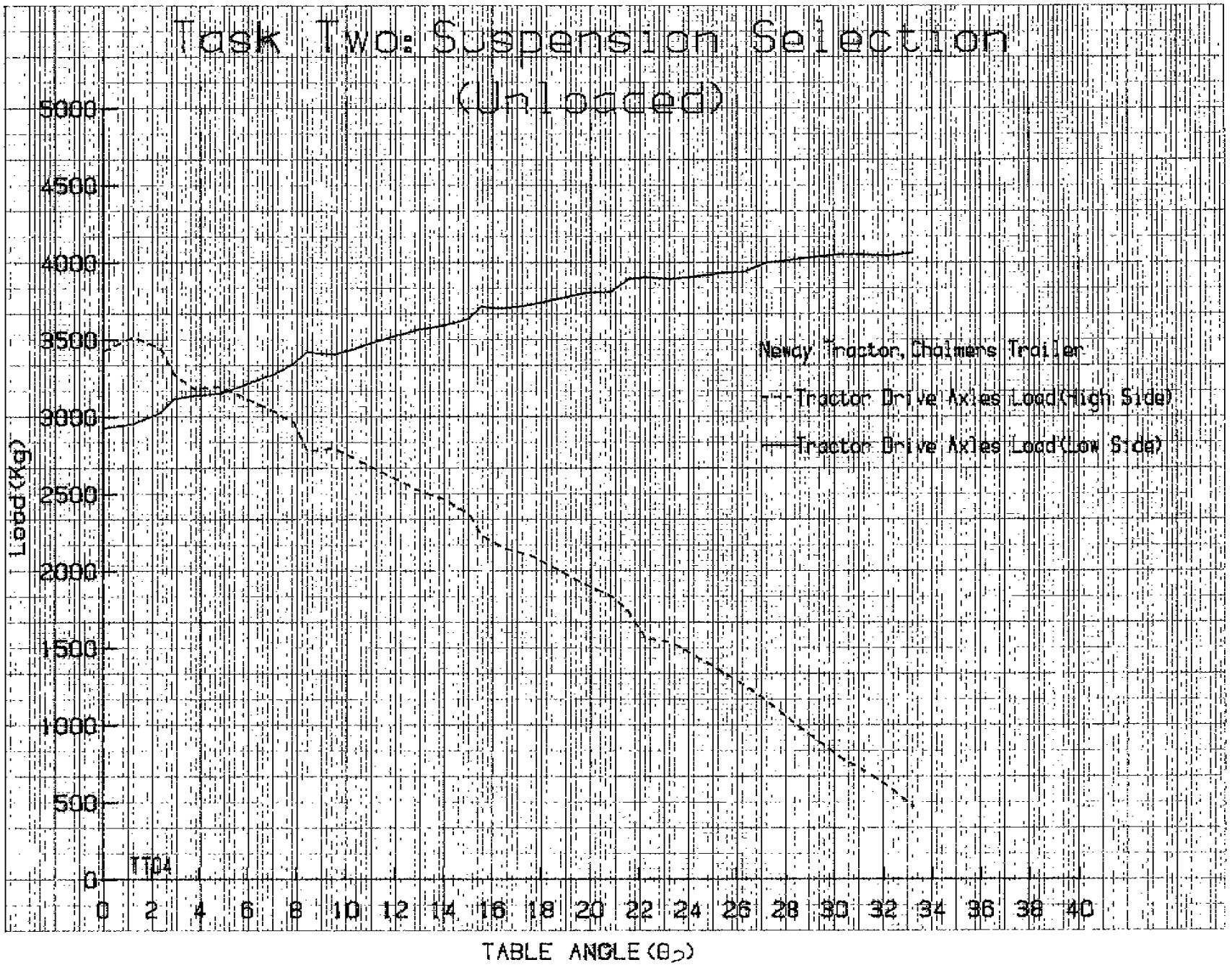
DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
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 ARD 244
SUSPENSION TYPE ON TRAILER	Chalmers 700
AXLE SPREAD ON TRACTOR	4,85M 1,55M
AXLE SPREAD ON TRAILER	1,69M
TRACK WIDTH ON TRACTOR	2,40M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,25M
AMBIENT TEMPERATURE	5°c


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ)
Neway Tractor, Challens Trailer
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)



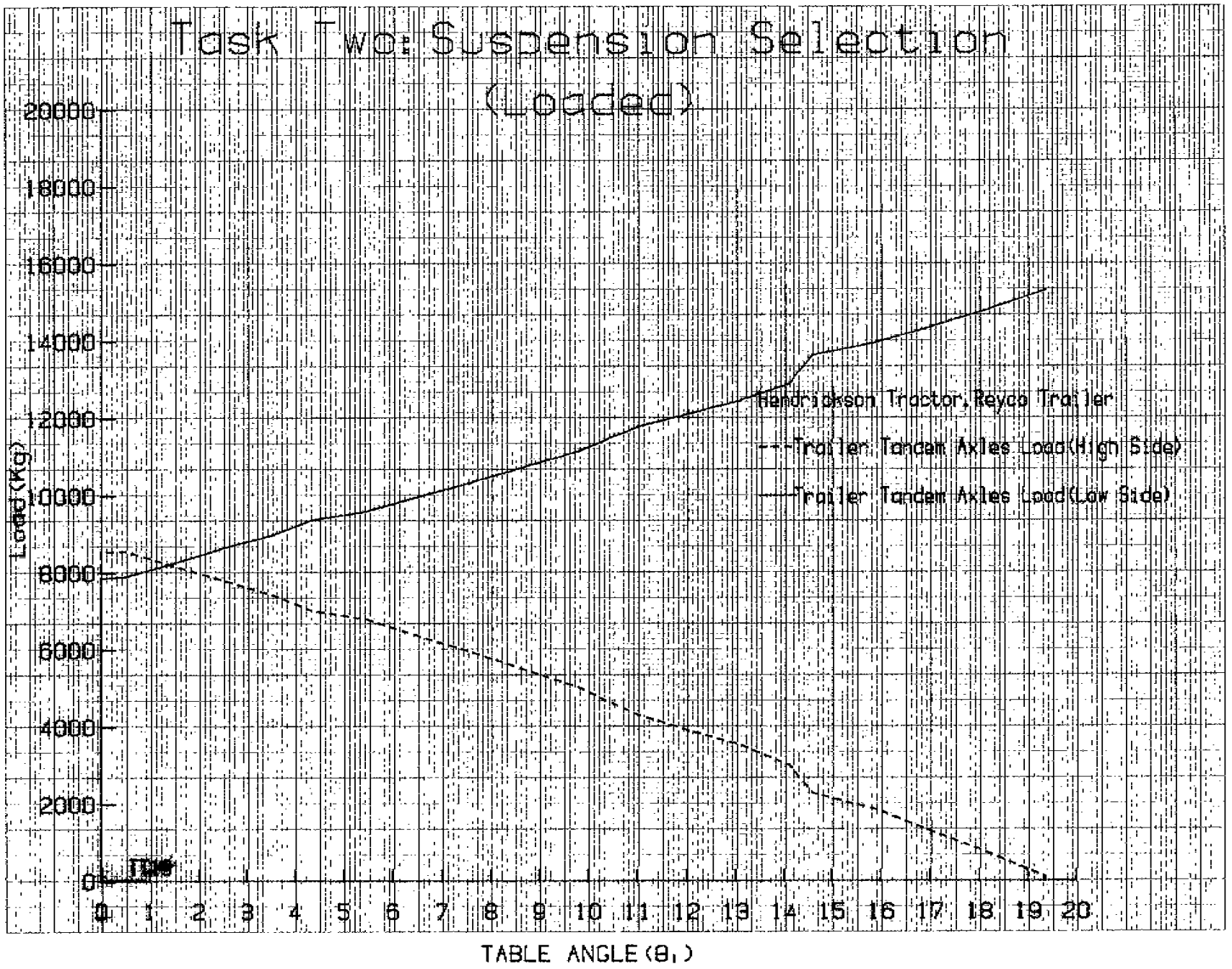

Task Two: Suspension Selection
(Unloaded)
Neway Tractor, Chalmer's Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)

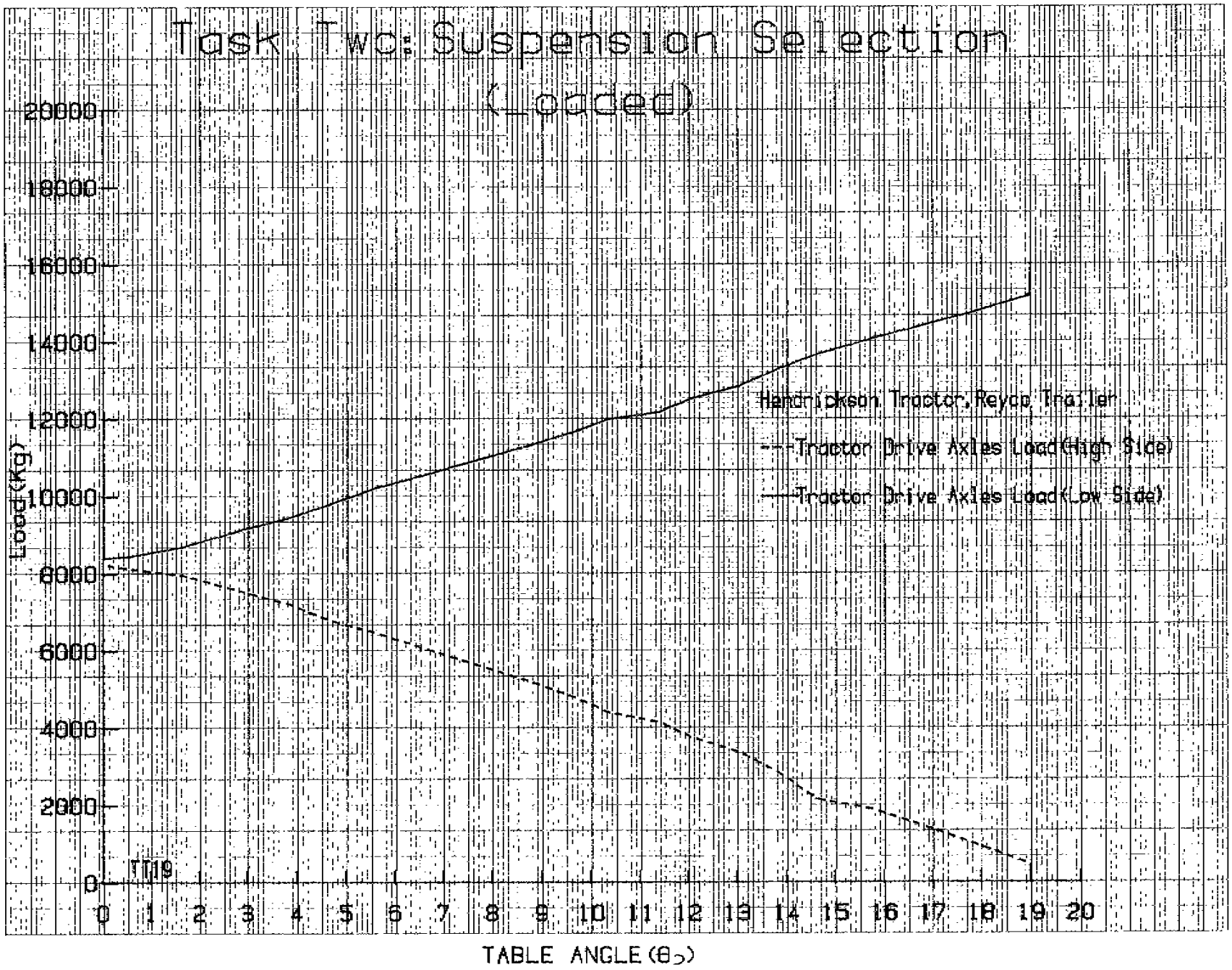

Task Two: Suspension Selection
(Unloaded)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TTD4
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ5)
Neway Tractor, Chalmers Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

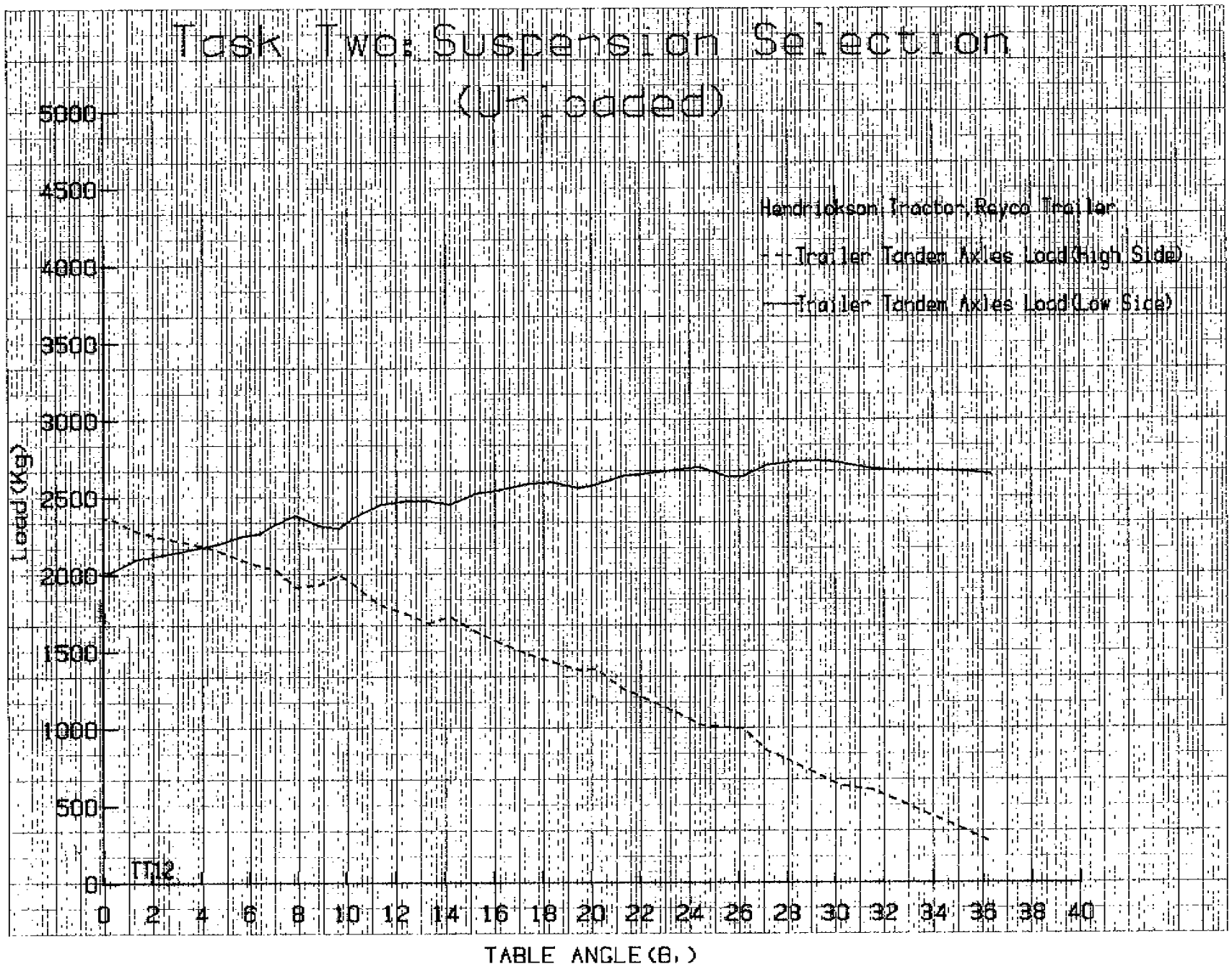
Task Two:Suspension Selection:

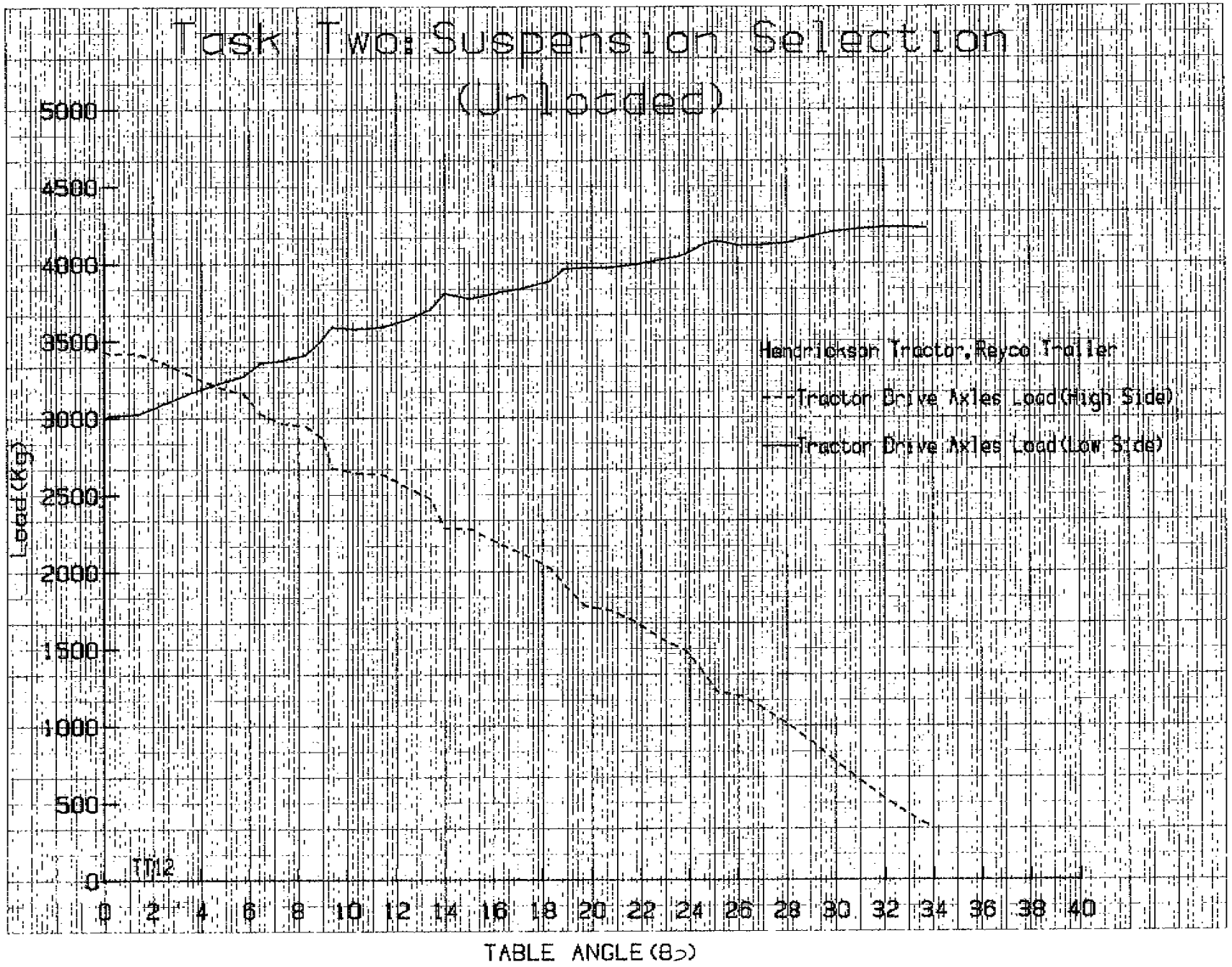
DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	8,02M
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	Hendrickson RTE 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	2,25M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,21M
AMBIENT TEMPERATURE	10°C


Task Two: Suspension Selection
(Loaded)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE(θ1)
Hendrickson Tractor,Reyco Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)


Task Two: Suspension Selection
(Loaded)
Hendrickson Tractor, Reyco Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ5)

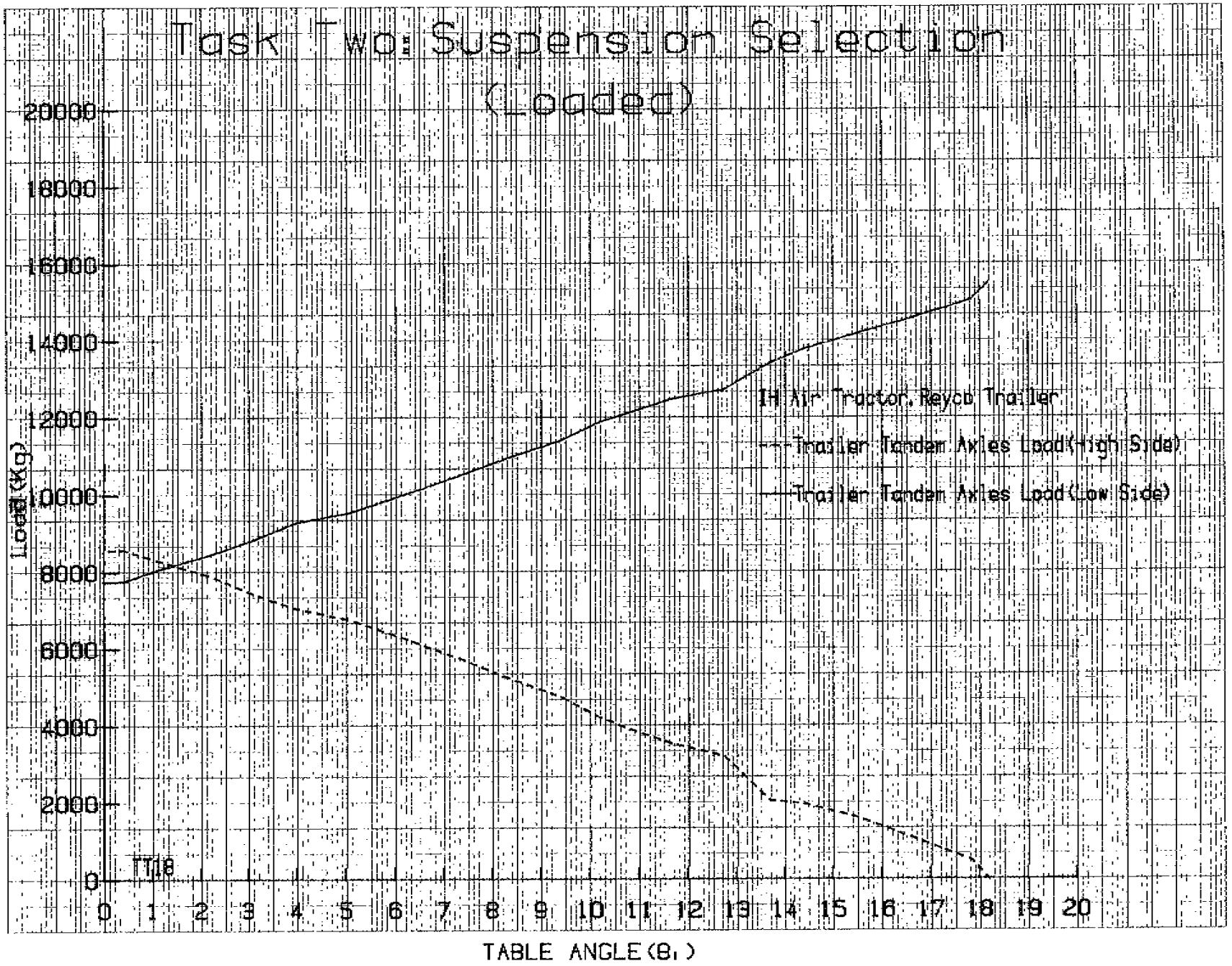

Task Two: Suspension Selection
(Unloaded)
Hendrickson Tractor, Reyco Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT12
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(θ.)

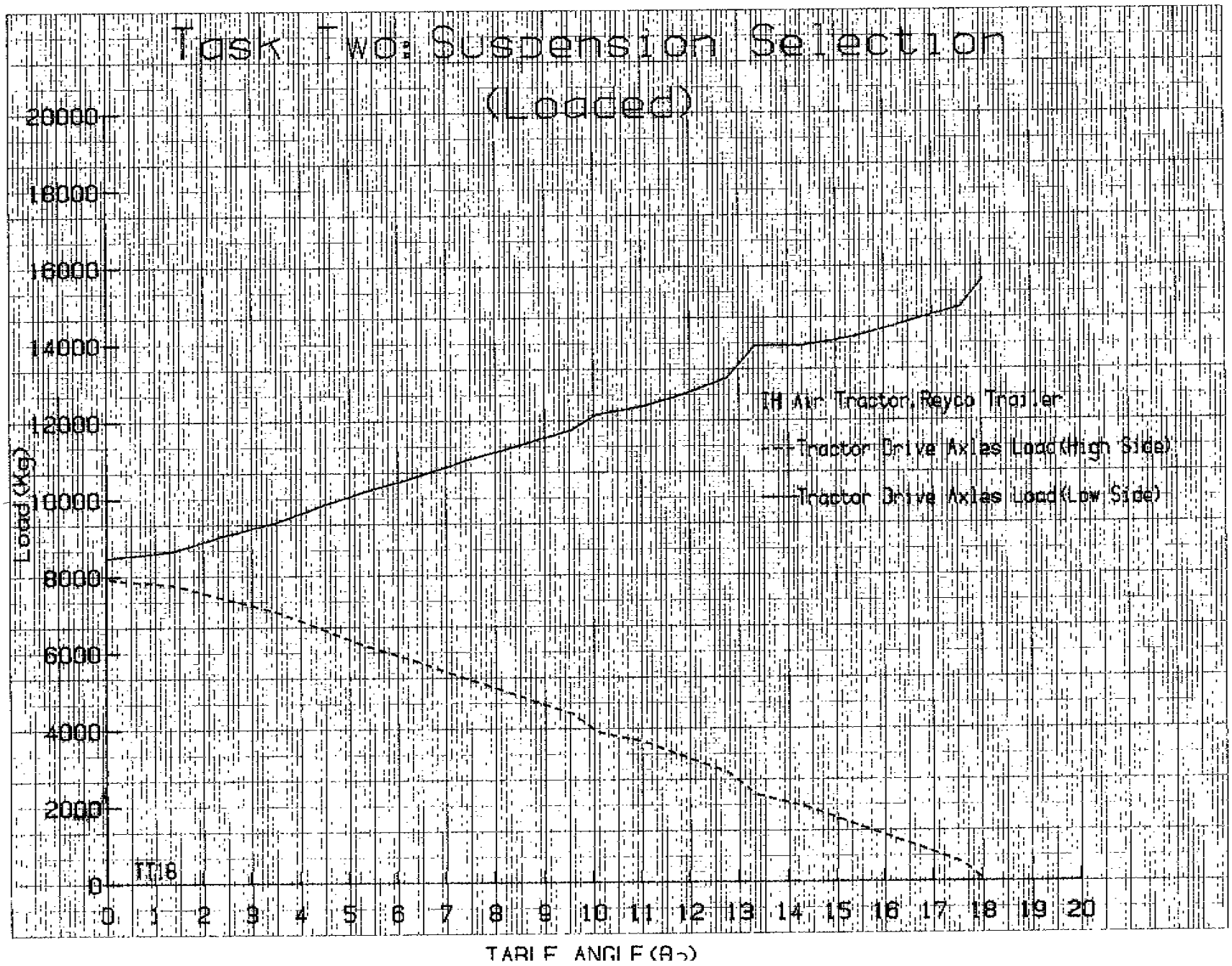


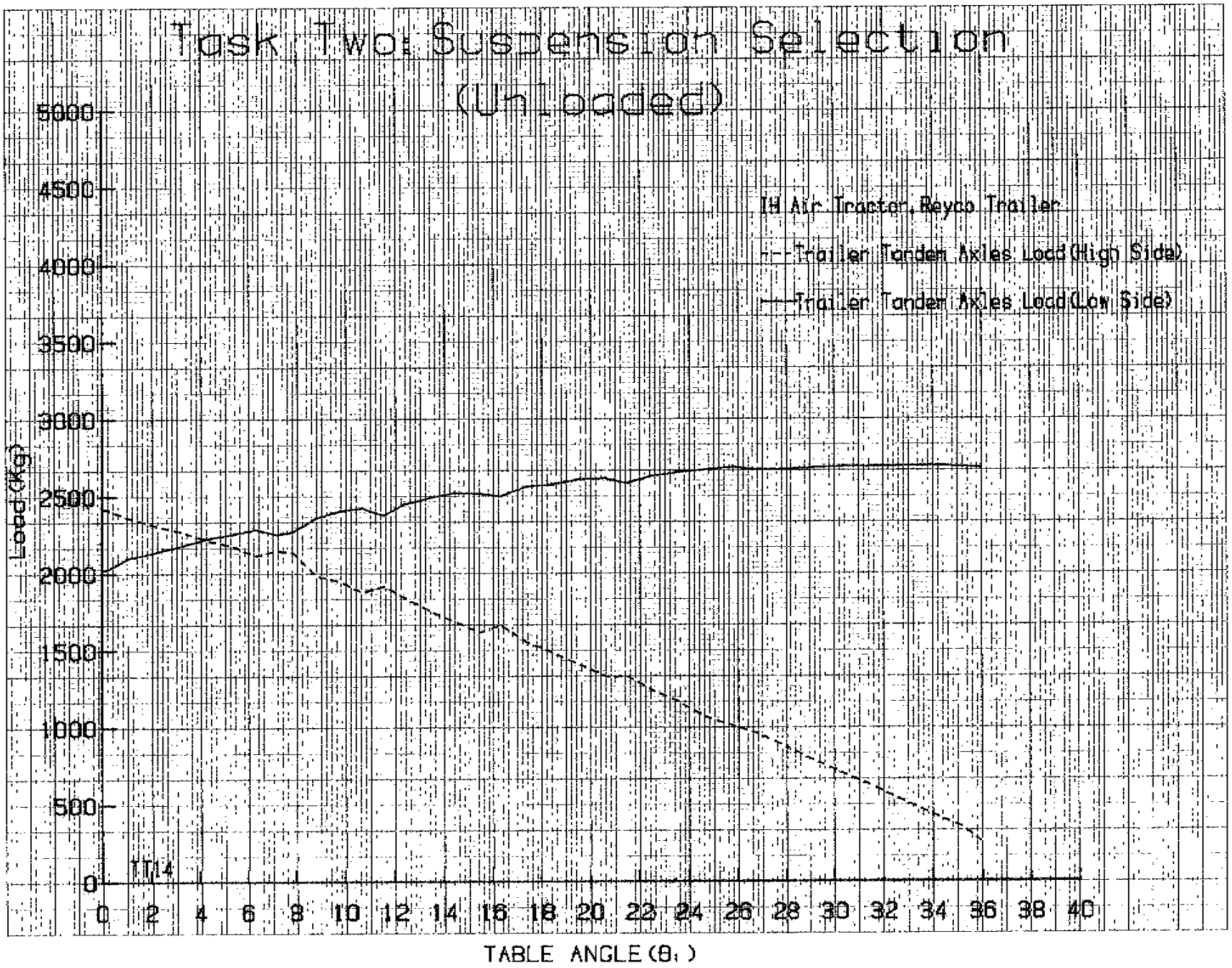
Task Two:Suspension Selection

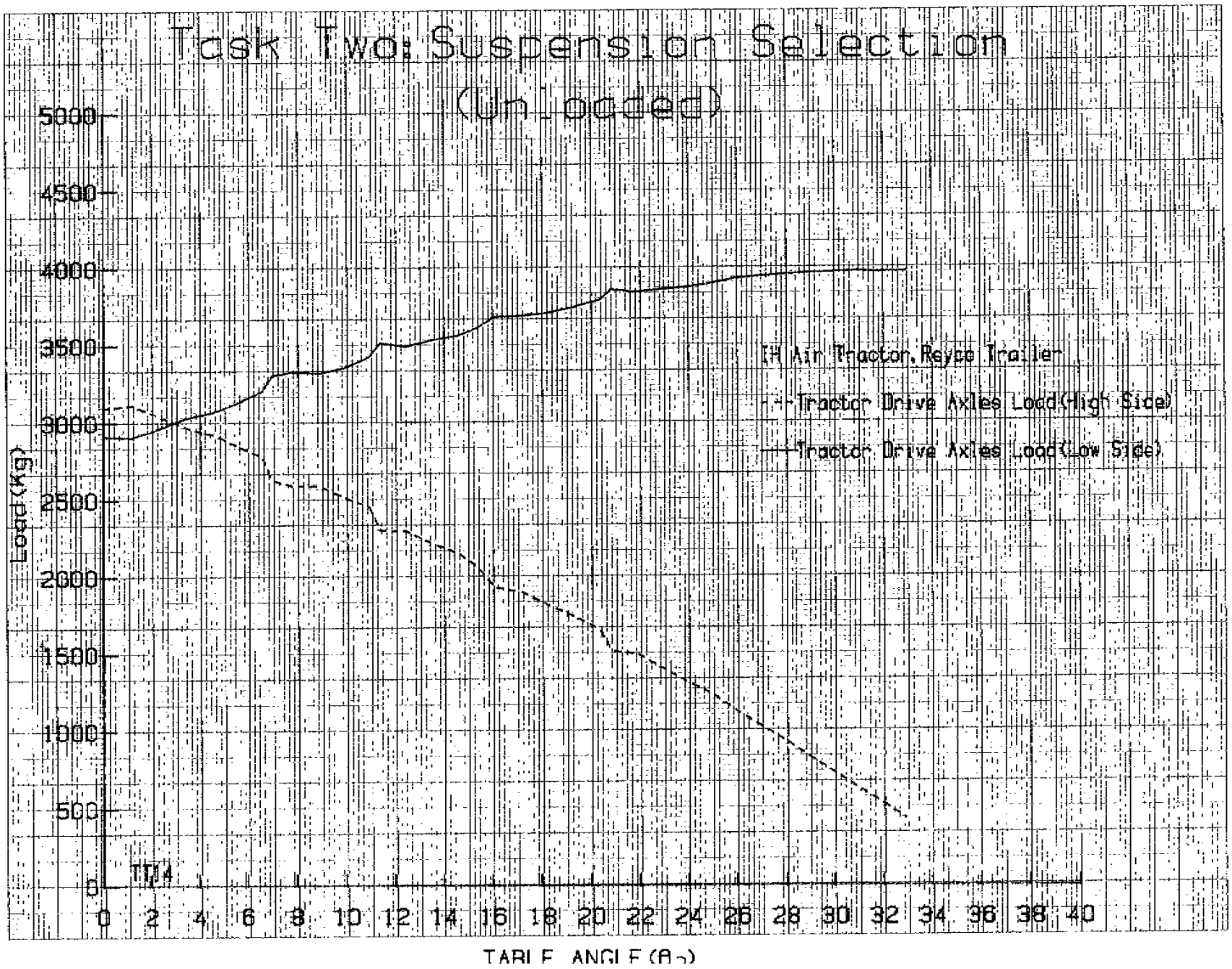
DESCRIPTION

TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,57M
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 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
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c




Task Two: Suspension Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TARIF ANGLE (A)
IH Air Tractor, Reyco Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

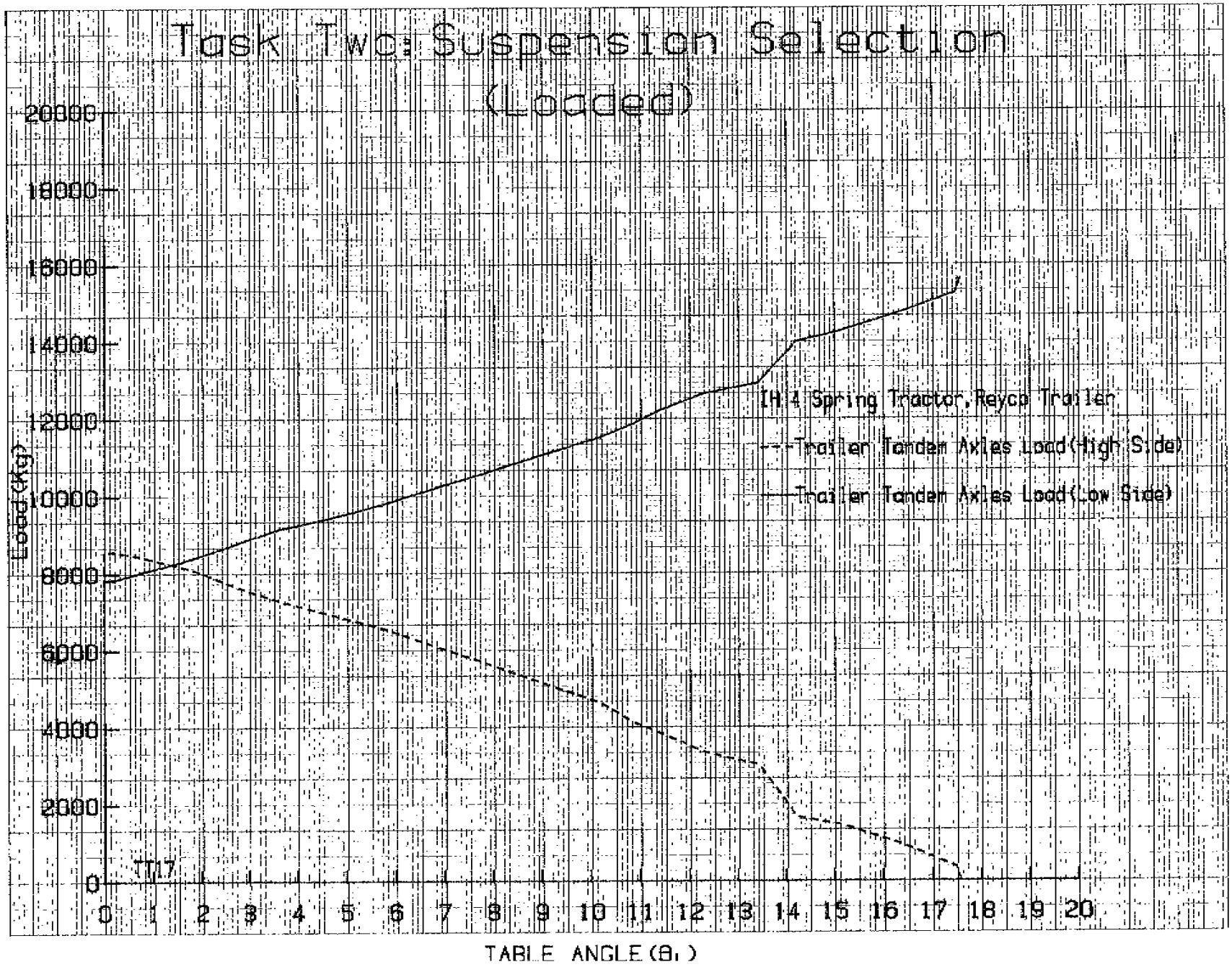

Task Two: Suspension Selection
(Unloaded)
IH Air Tractor, Reyco Trailer
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)

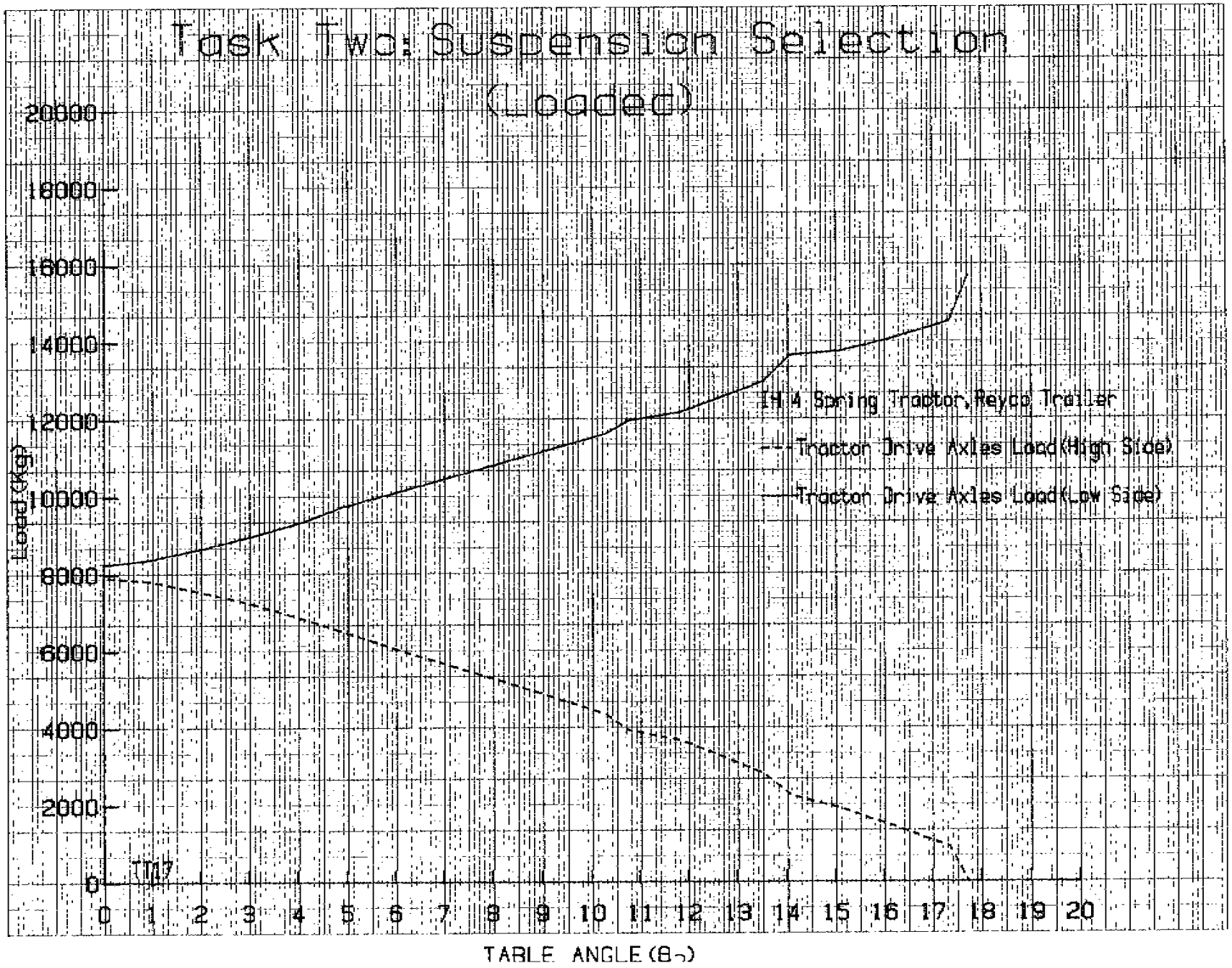

Task Two: Suspension Selection
(Un-loaded)
IH Air Tractor, Reyco Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

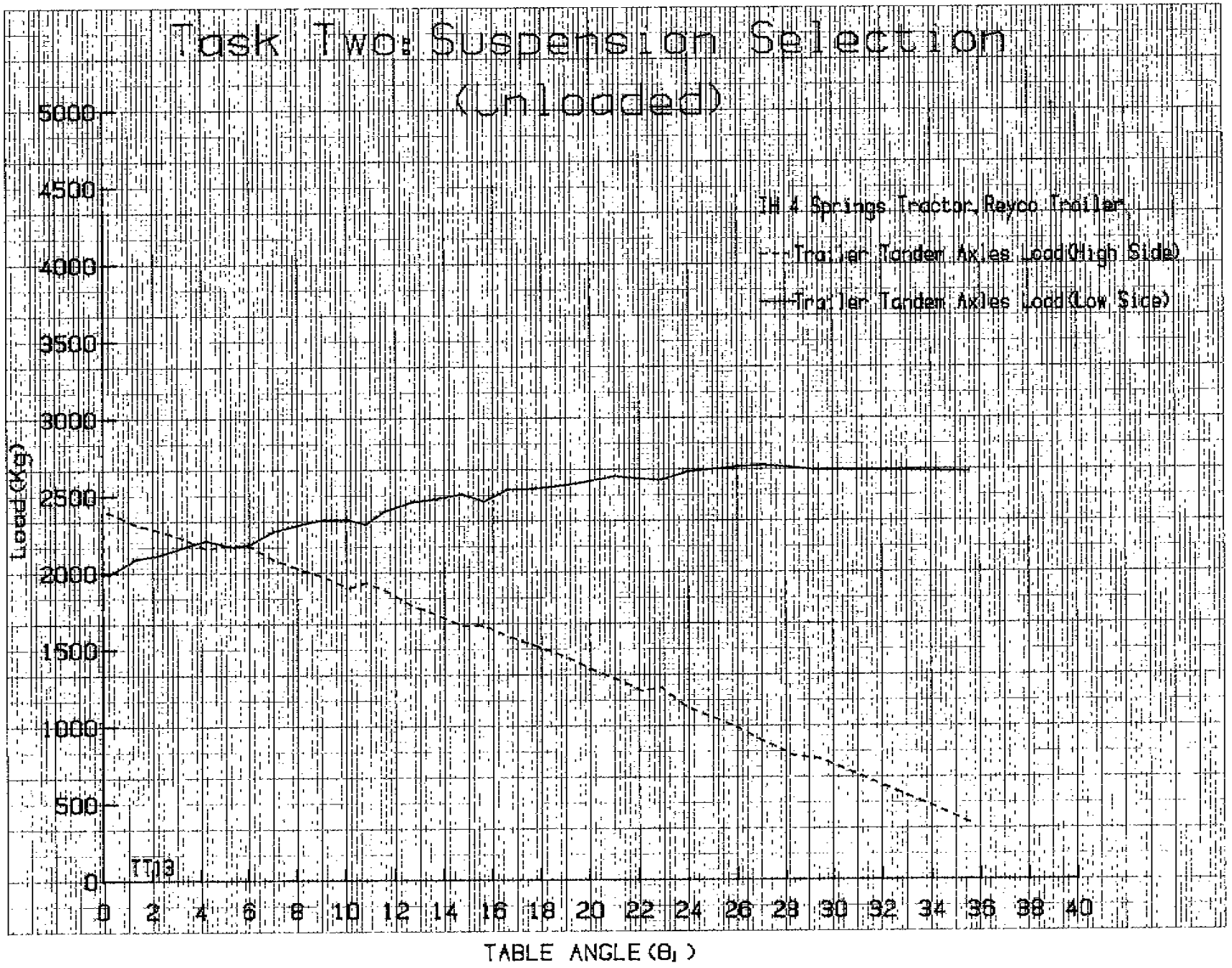
Task Two:Suspension Selection

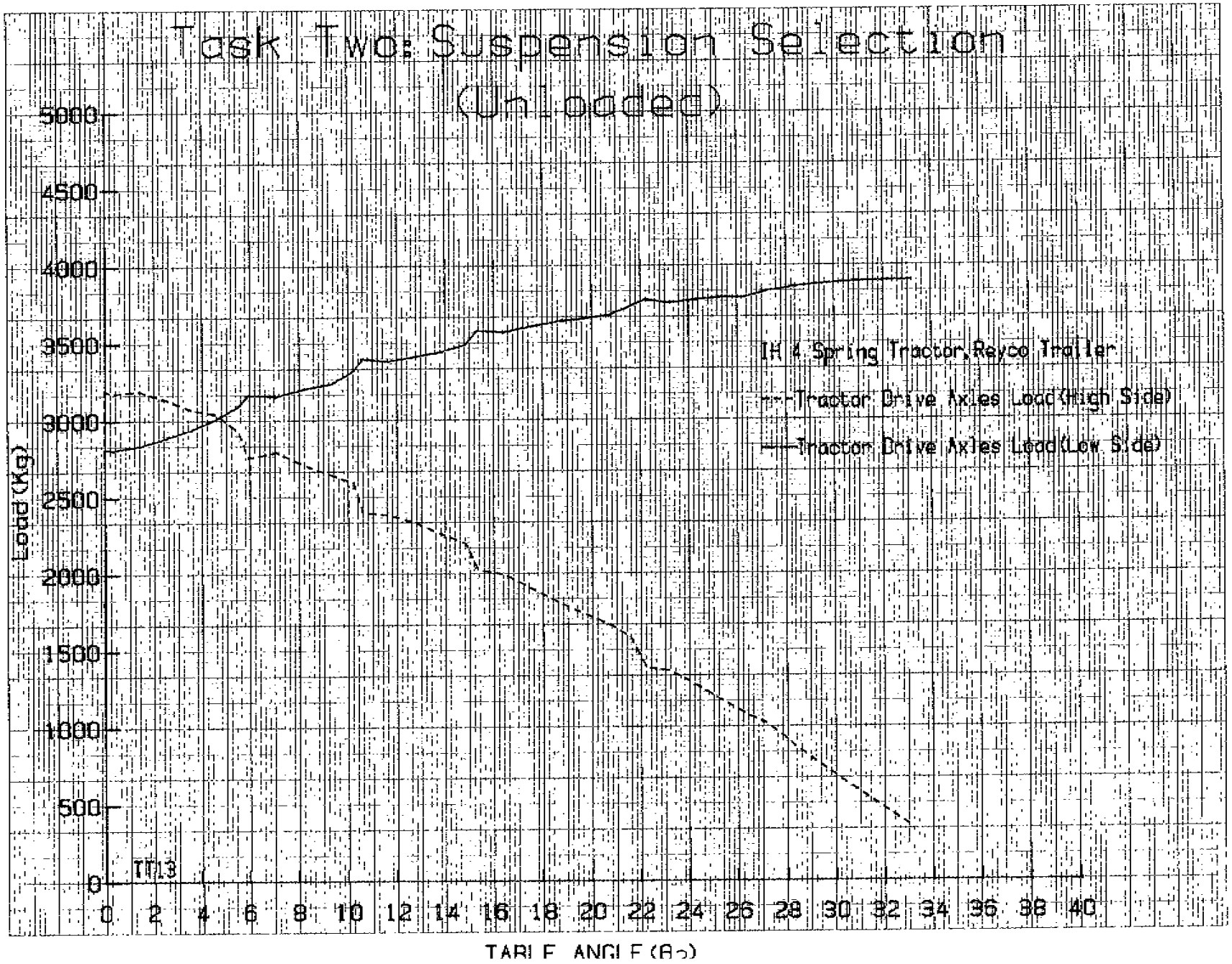
DESCRIPTION

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 X2A
TIRE TYPE ON TRAILER	Michelin Radial 11R 22.5 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	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c


Task Two: Suspension Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ1)
IH 4 Spring Tractor, Reyco Trailer
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)


Task Two: Suspension Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ)
IH 4 Spring Tractor,Reyco Trailer
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

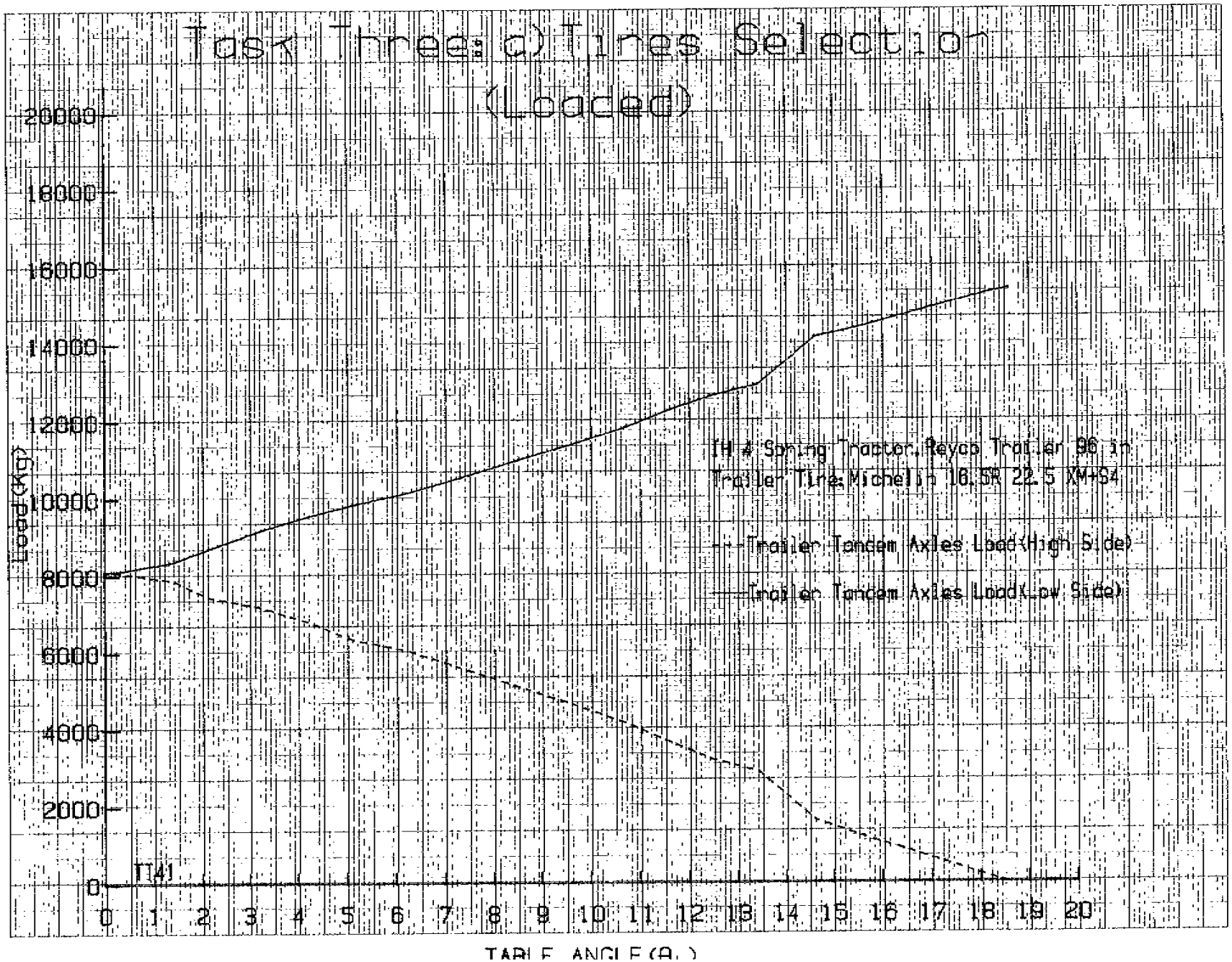

Task Two: Suspension Selection
(Unloaded)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Load(Kg)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)
4 Springs Tractor,Reyco Trailer
Trailer Tander Axles Load(High Side)
Trailer Tander Axles Load(Low Side)

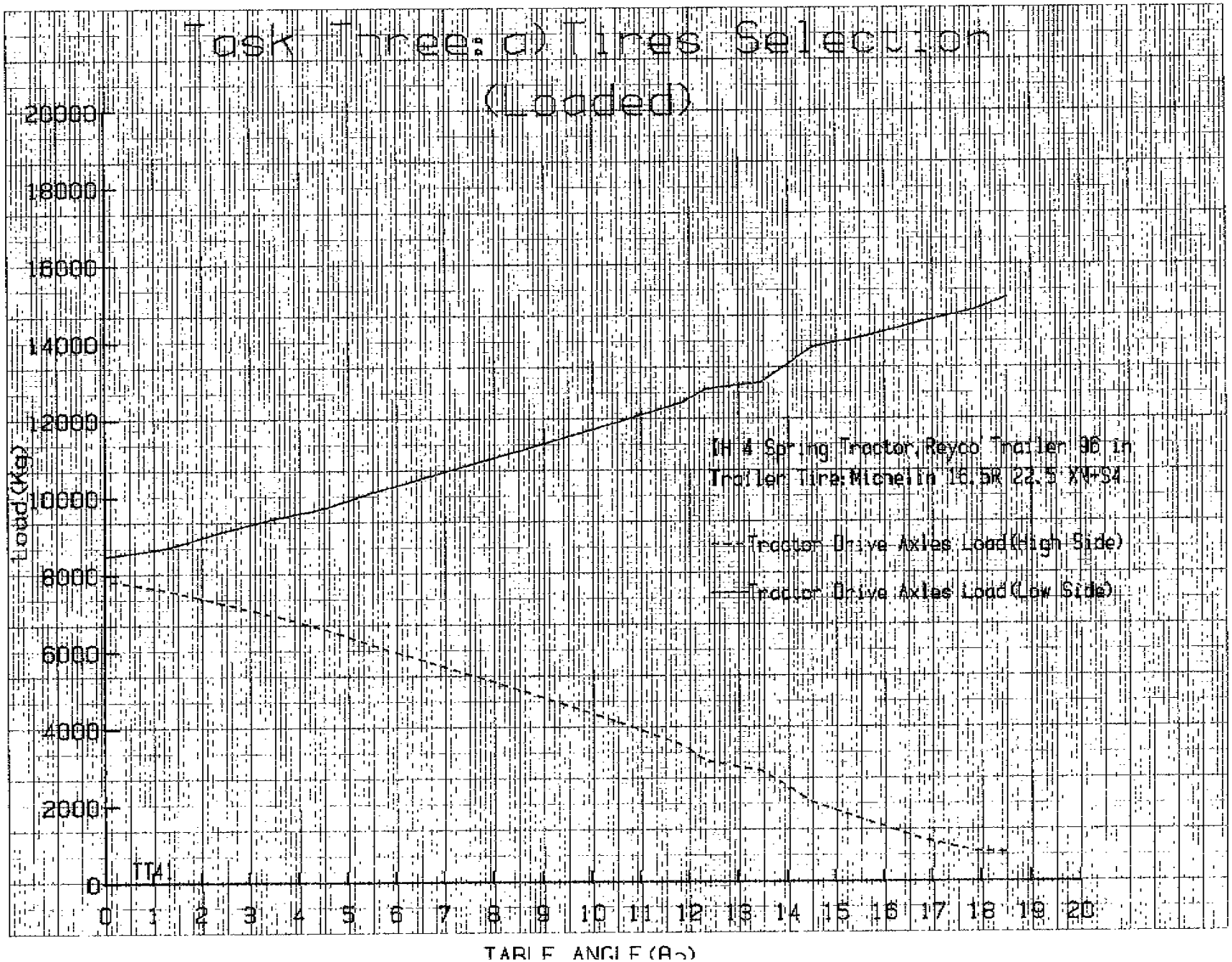


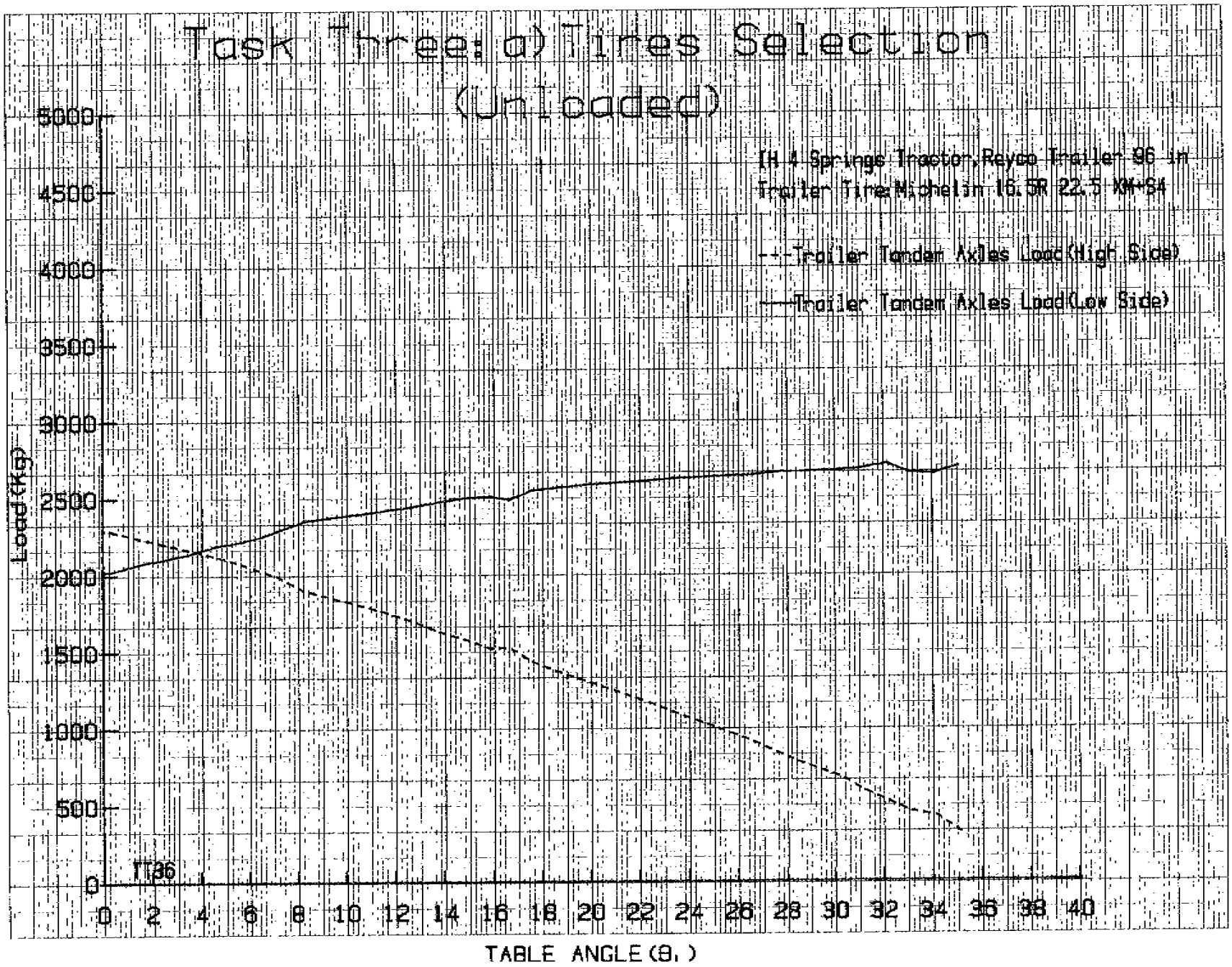
Test Three:A)Tires Selection

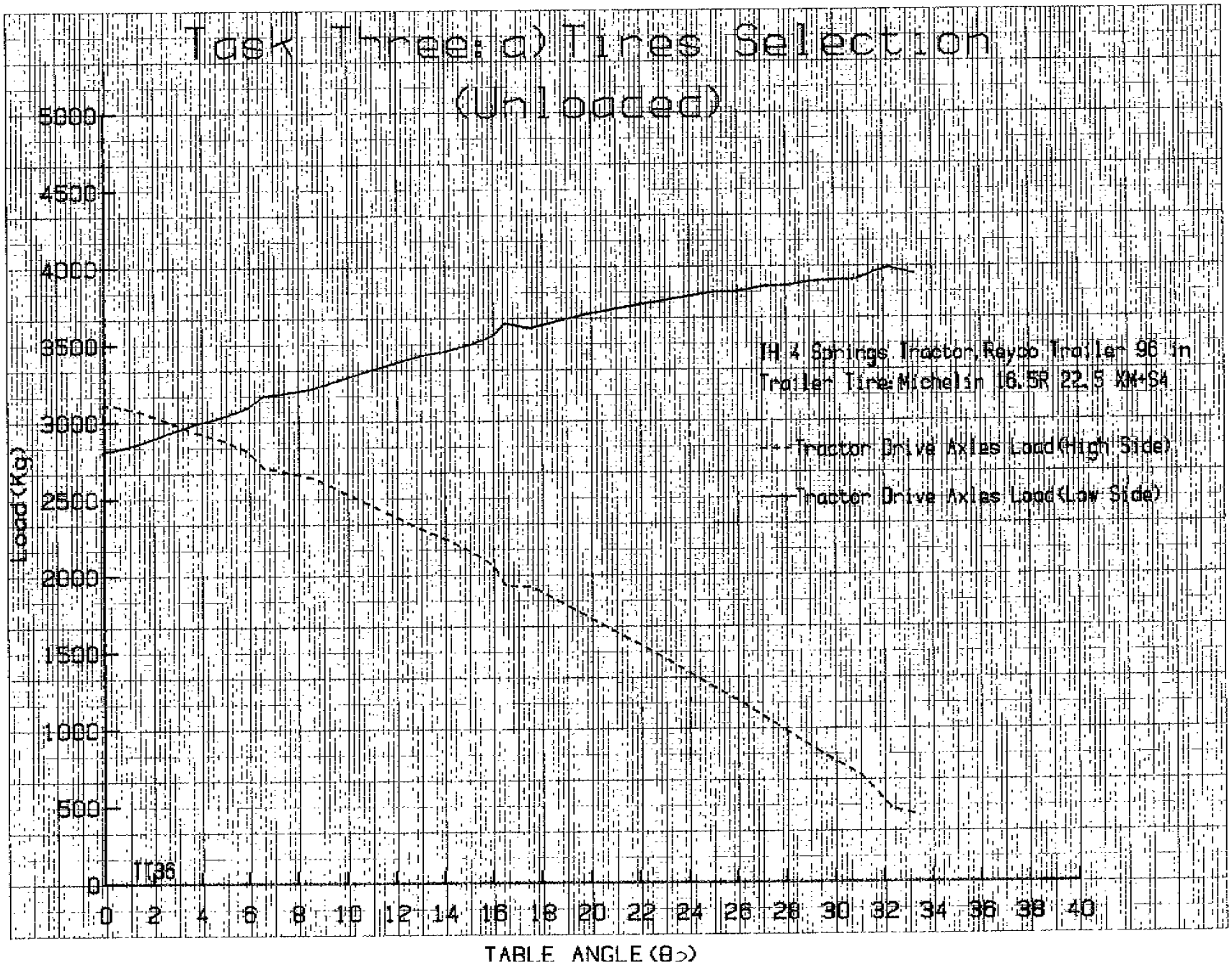
DESCRIPTION

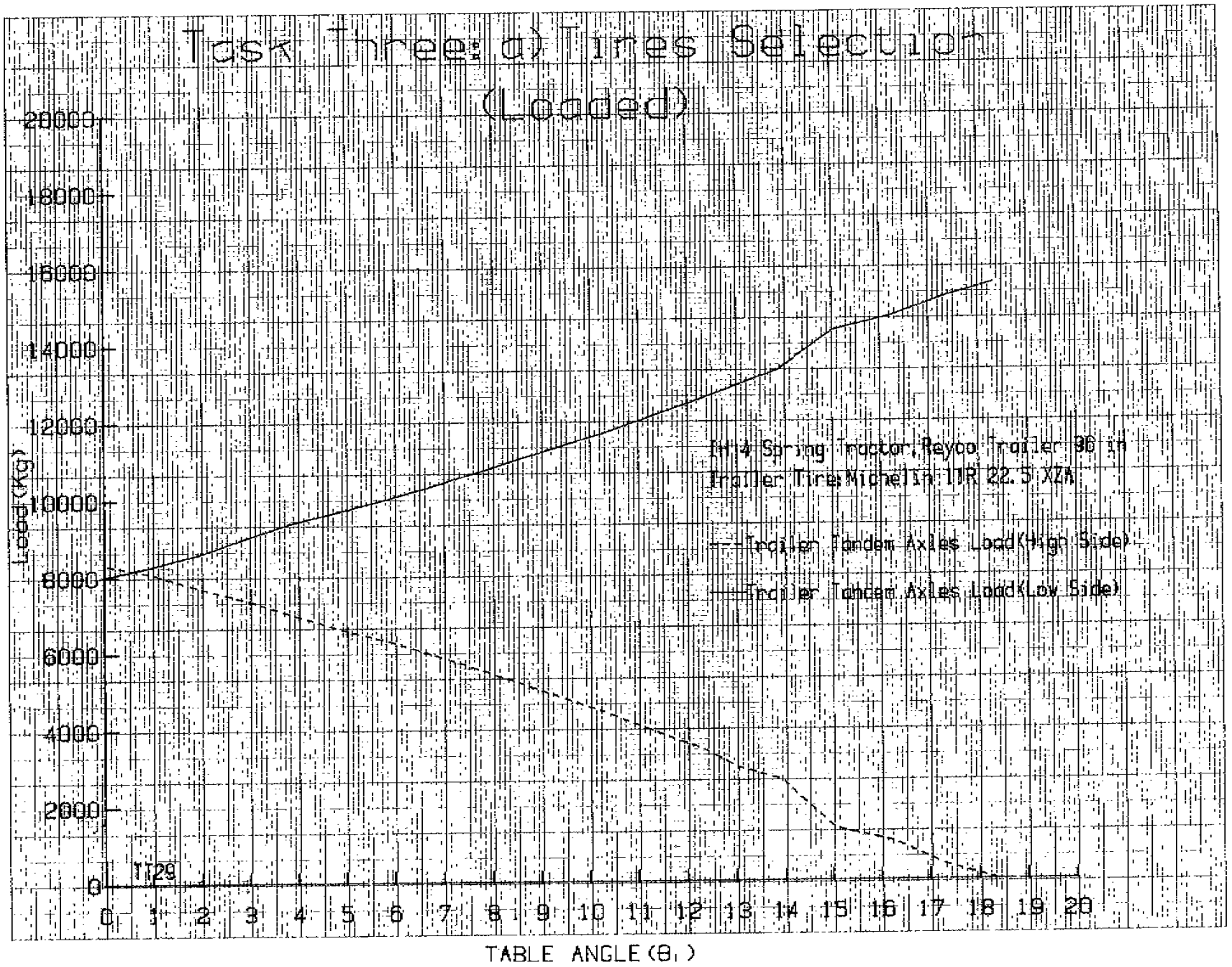
TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,72M
TRAILER LENGTH	14,78M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	1H 4 Springs
SUSPENSION TYPE ON TRAILER	Reyco 21B
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,70M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

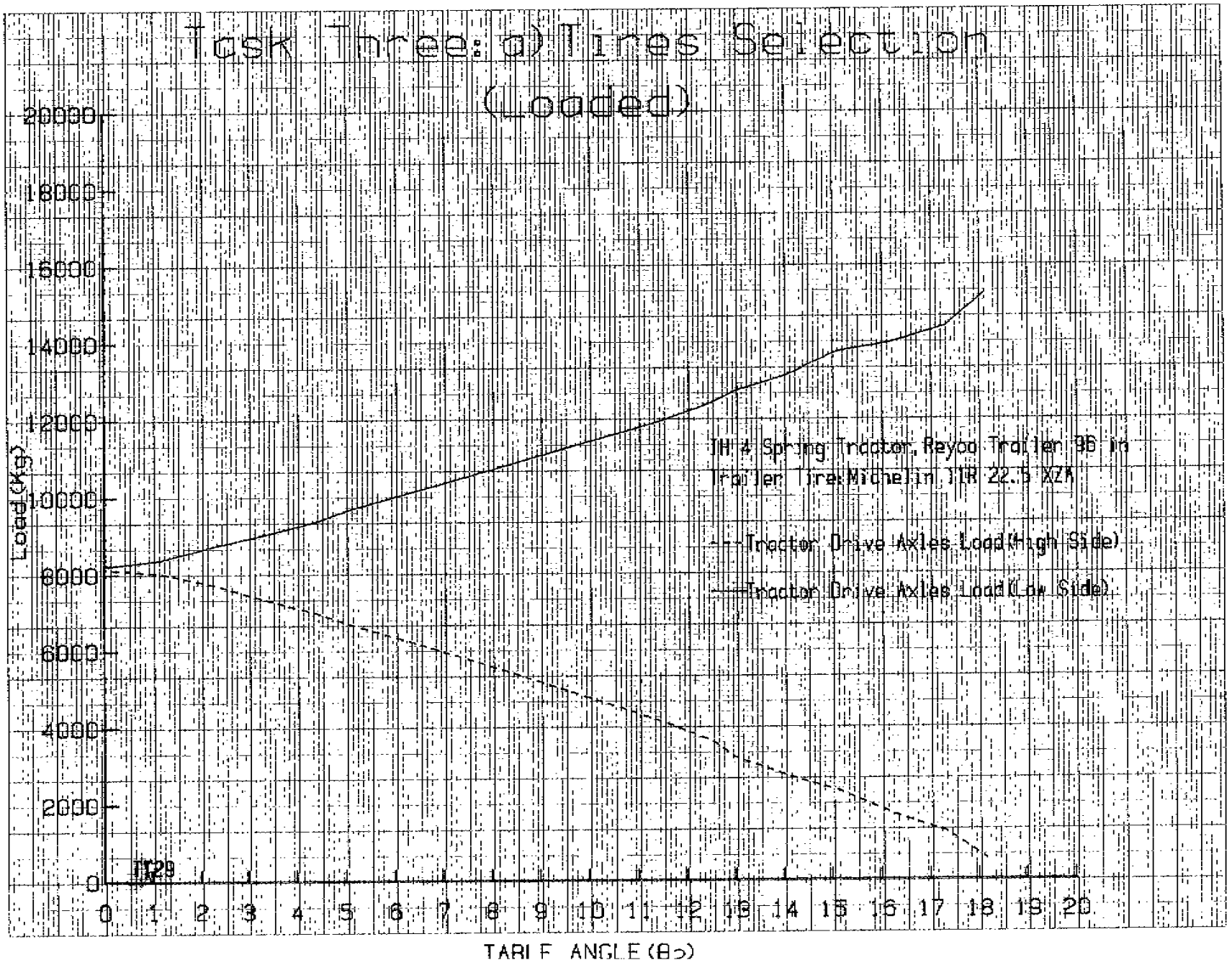

Task Three: a) Tires Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
T14)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TAPLE ANGLE (A.)
IH # Spring Tractor, Reyco Trailer 96 in
Trailer Tire: Michelin 16.5R 22.5 XM+S4
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)

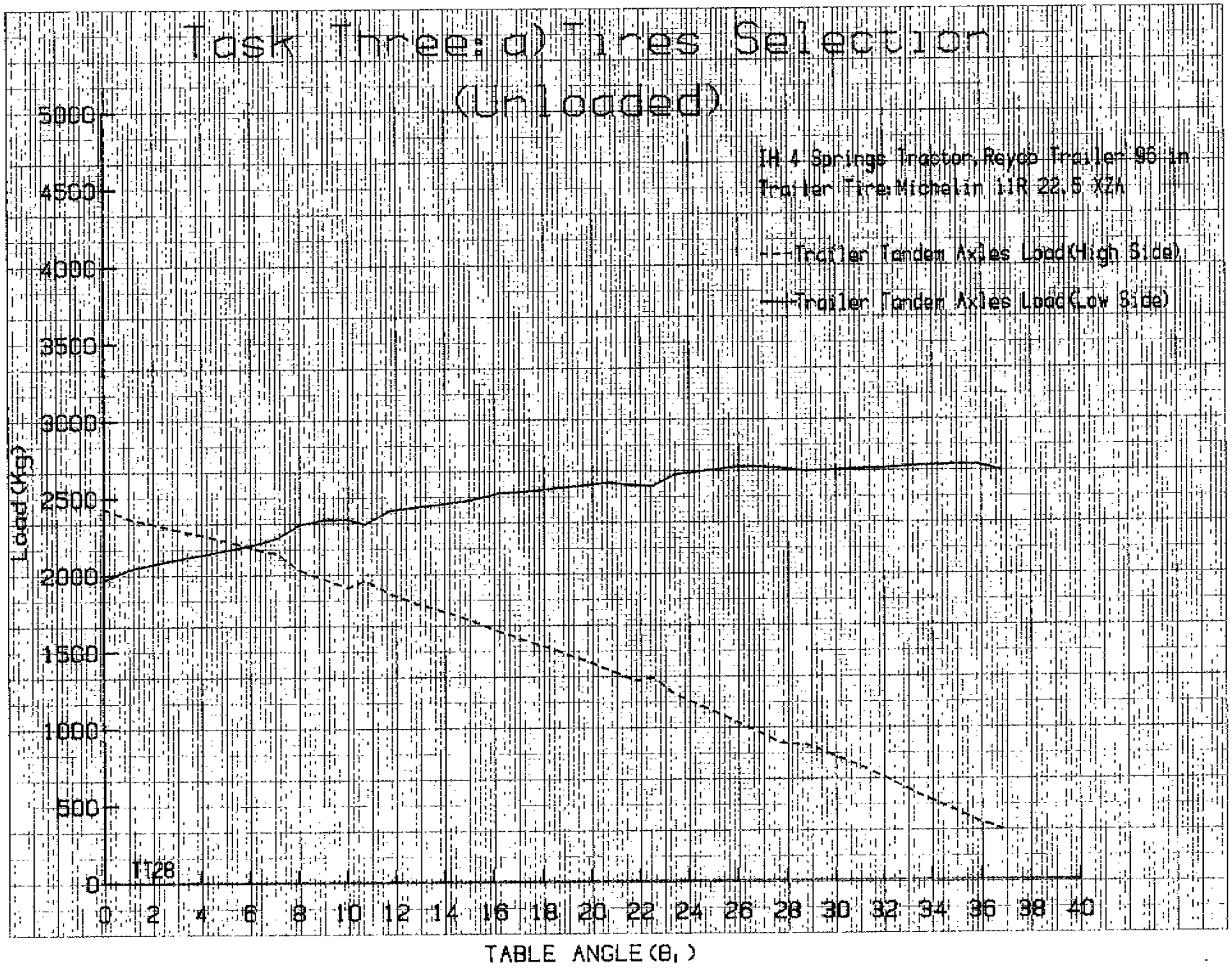


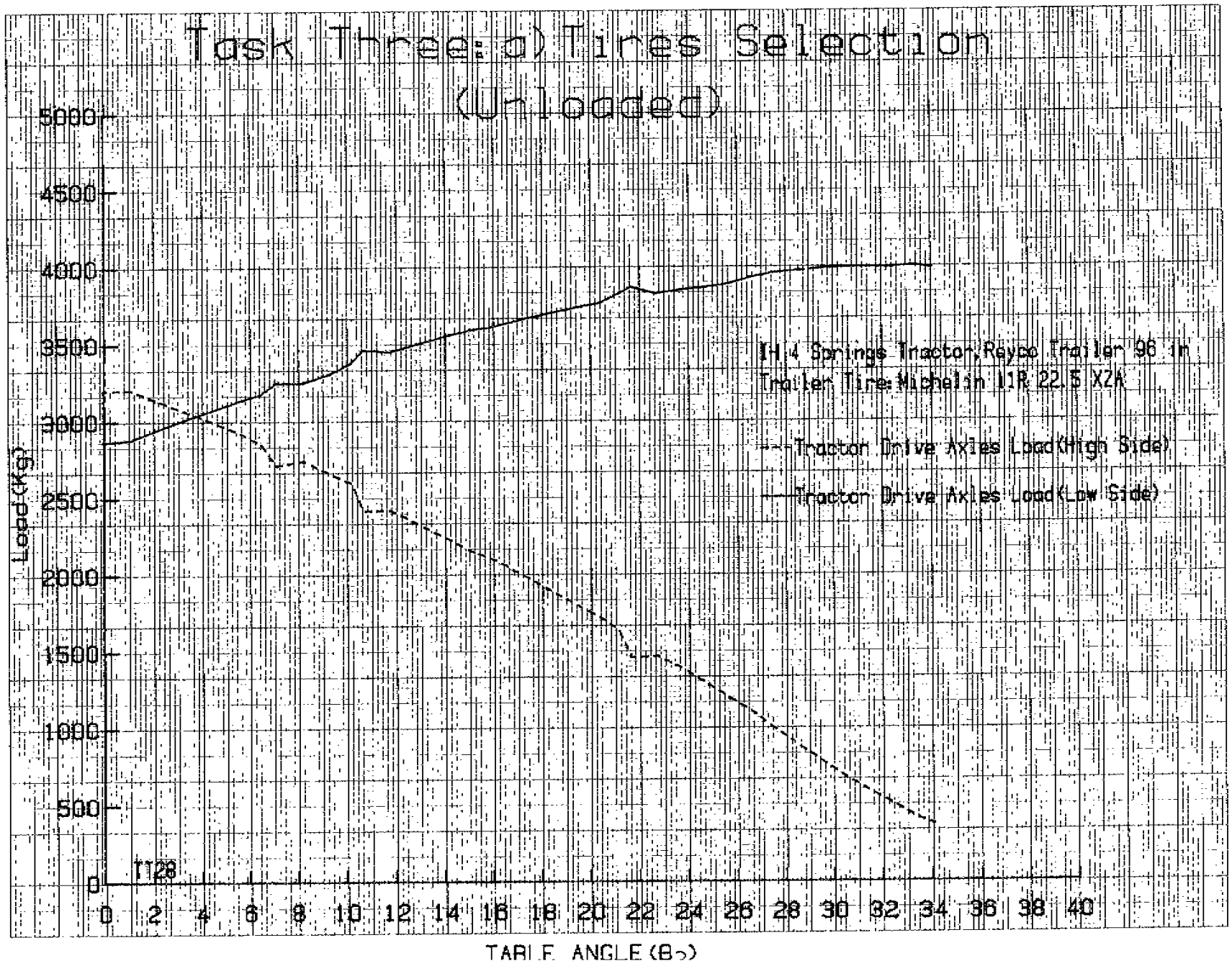

Task Three: a) Tires Selection
(Unloaded)
IH 4 Springe Tractor, Reyco Trailer 96 in
Trailer Tire: Michelin 16.5R 22.5 XM+S4
---Trailer Tandem Axles Load(High Side)
——Trailer Tandem Axles Load(Low Side)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT36
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ,)

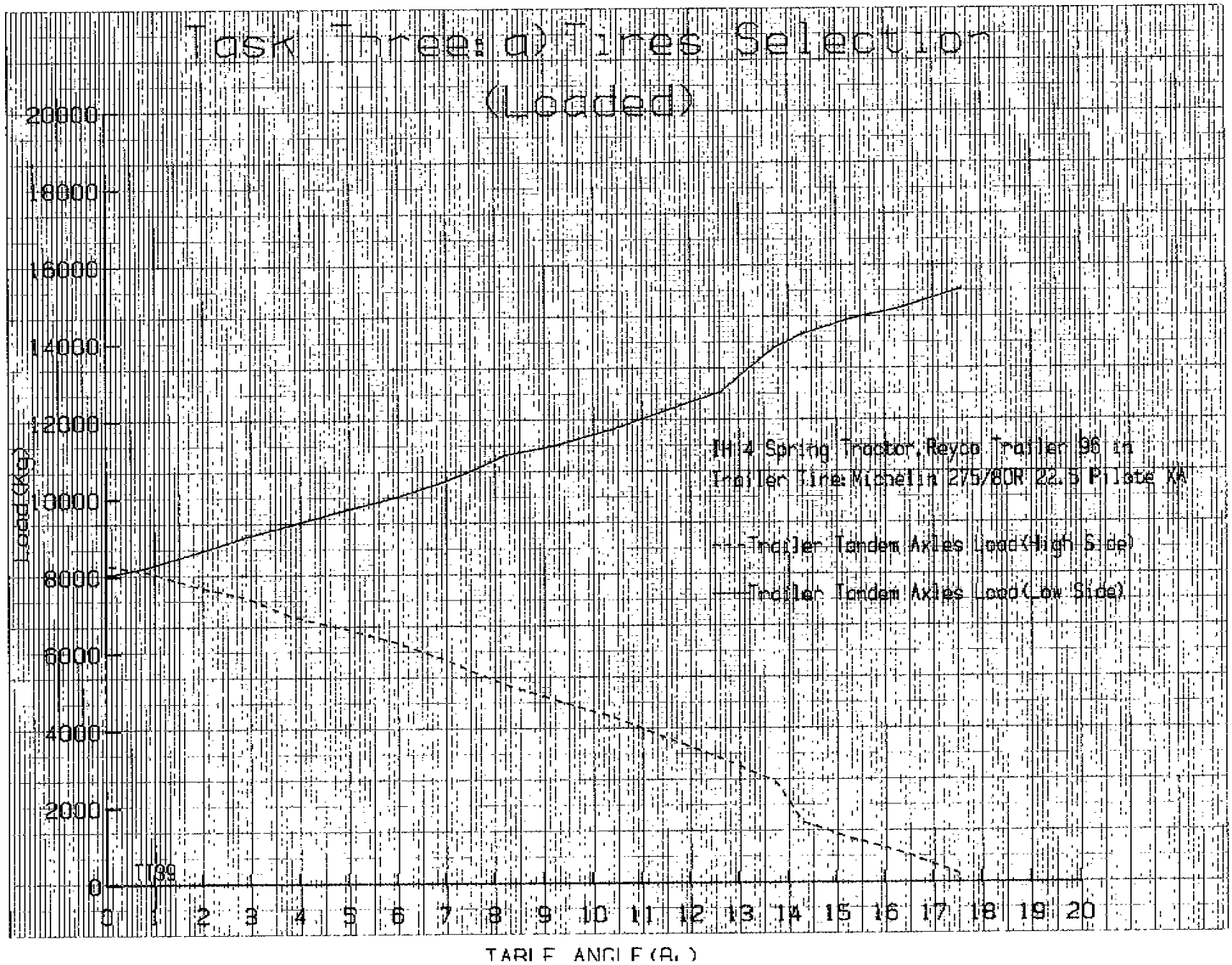


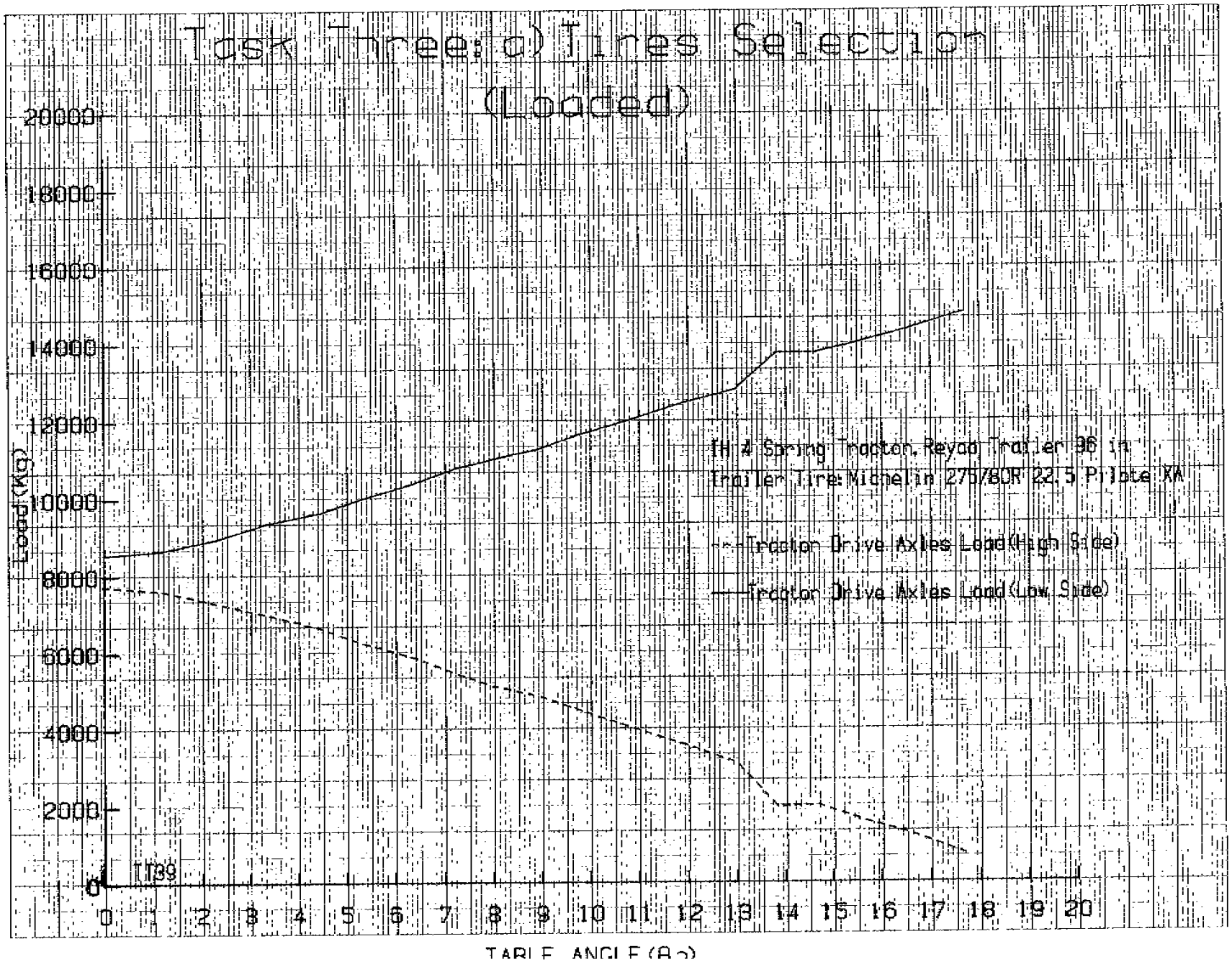

Task three: a) Tires selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load(Kg)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ1)
1129
IH 4 Spring Tractor, Reyco Trailer 36 in
Trailer Tire:Michelin 11R 22.5 XZA
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)

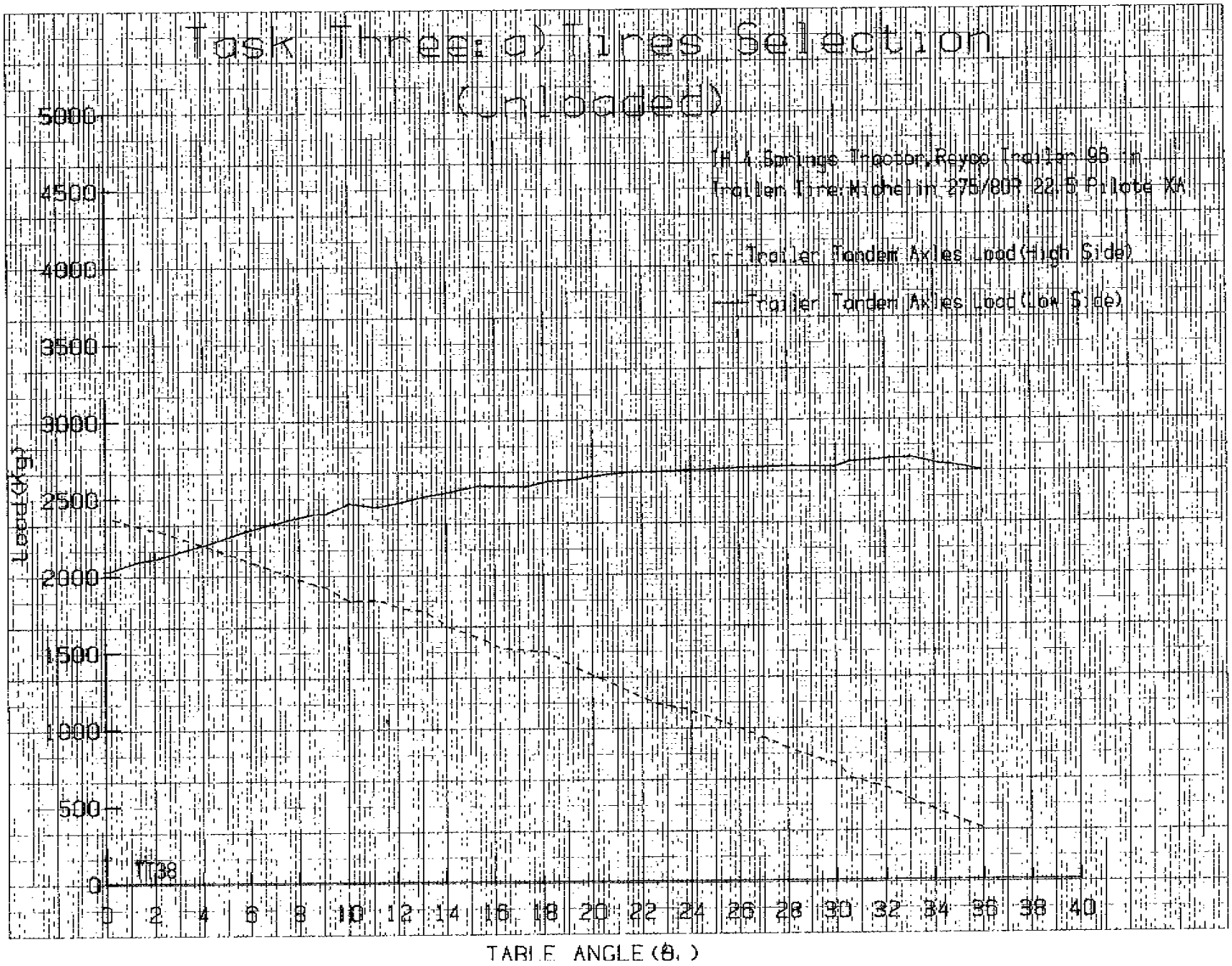

Task Tread Lines Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TARIF ANGLE (θ)
JH 4 Spring Tractor, Reyco Trailer 96 in
Trailer Tire: Michelin 11R 22.5 XZA
---Tractor Drive Axles Load(High Side)
——Tractor Drive Axles Load(Low Side)

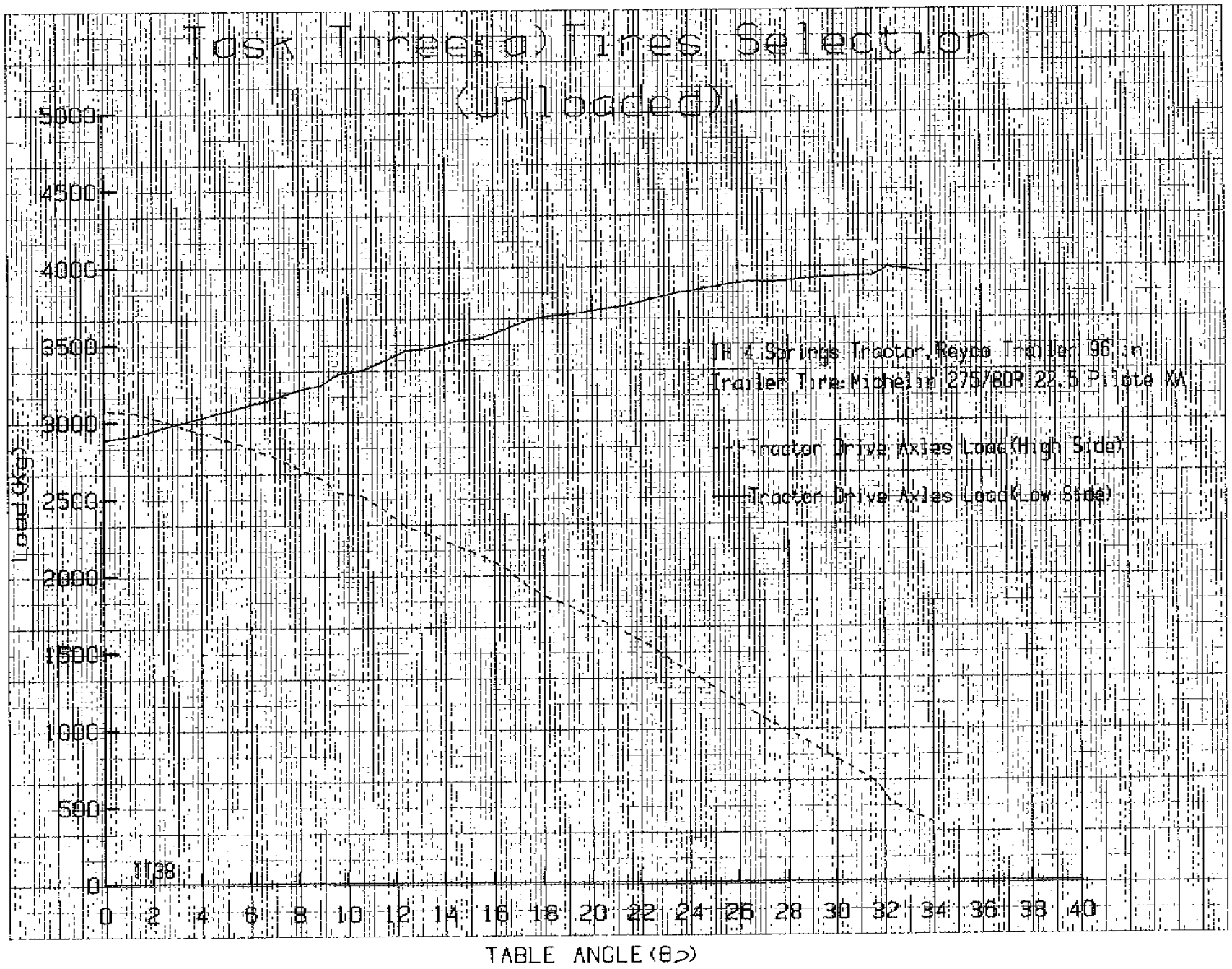

Task three: a) Tires Selection
(Unloaded)
IH 4 Springs Tractor,Reyco Trailer 96 in
Trailer Tire:Michelin 11R 22.5 XZA
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
T128
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ,)

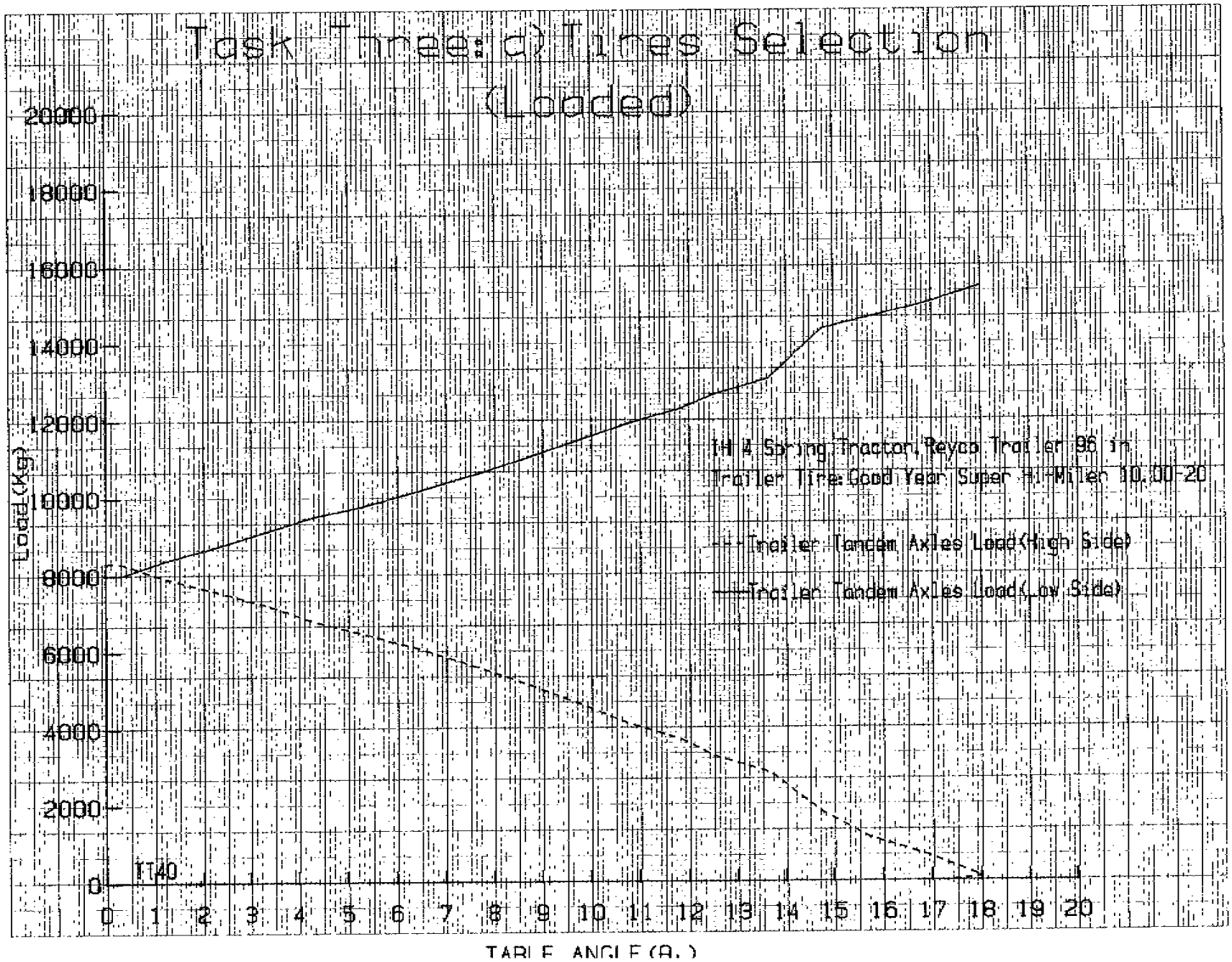

Task Three: a) Tires Selection
(Unloaded)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Load (Kg)
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ)
H 4 Springs Tractor,Reyco Trailer 96 in
Trailer Tire:Michelin 11R 22.5 XZA
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

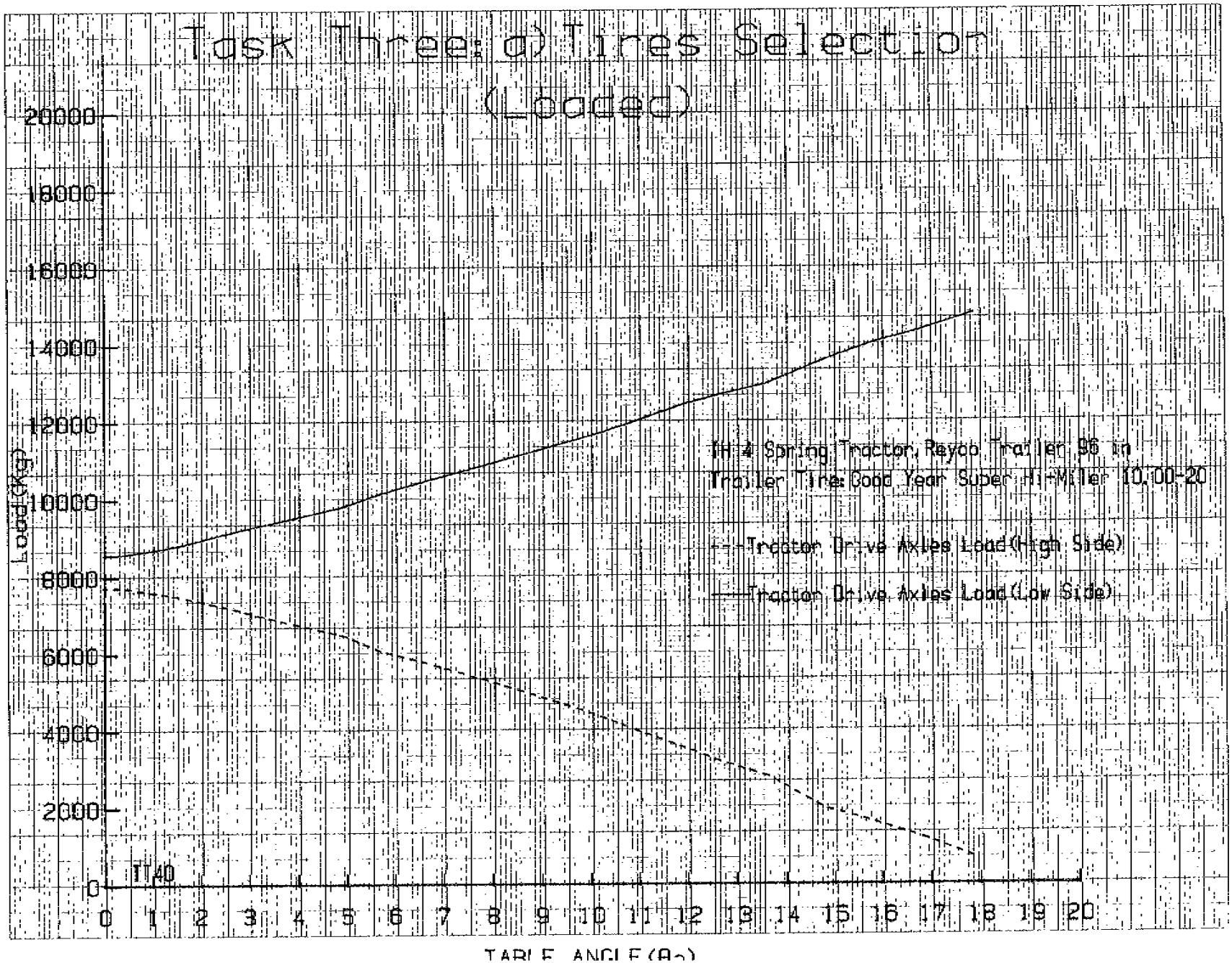

Tash Tread Tires Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
TARI E ANGLE (A,)
IH 4 Spring Tractor, Reyco Trailer 96 in
Trailer Tire: Michelin 275/80R 22.5 Pilote XA
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)

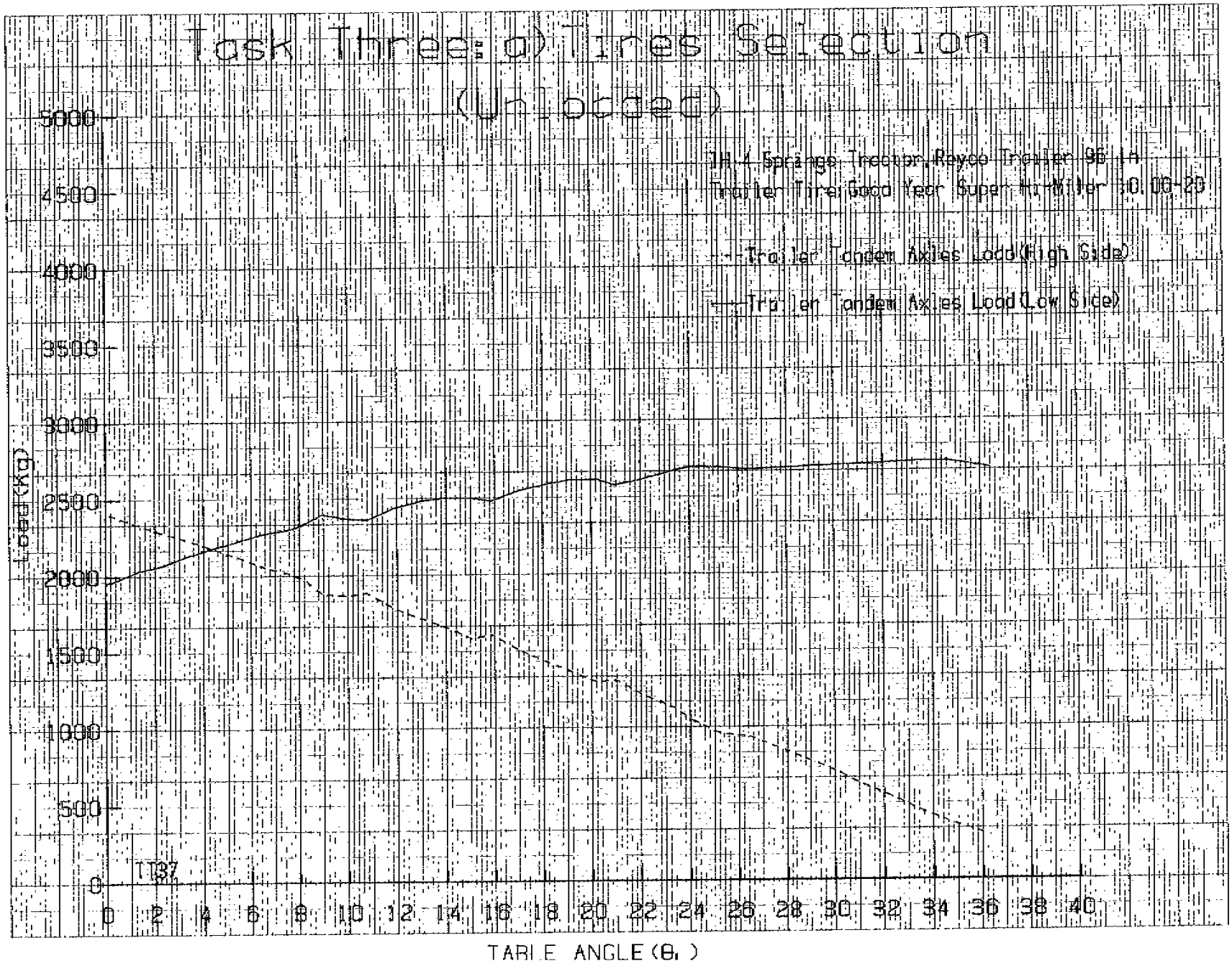

Tandem Tires Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load(Kg)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
TABLE ANGLE(Deg)
TH 4 Spring Tractor, Reyco Trailer 96 in
Trailer Tire:Michelin 275/80R 22.5 Pilote XM
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

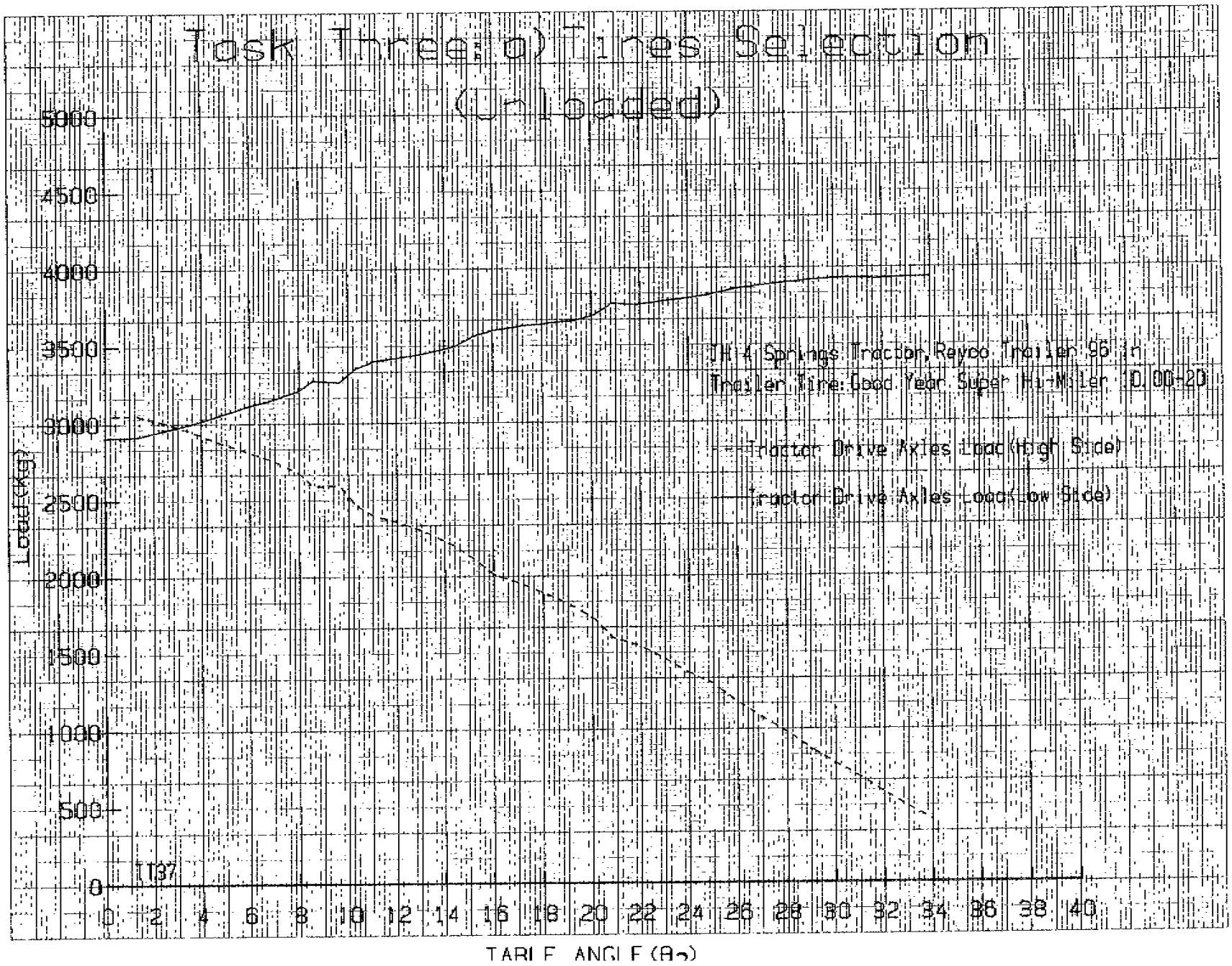





Task Time(Times Selection
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load (Kg)
1140
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TARLE ANGLE (A.)
IH 4 Spring Tractor, Reyco Trailer 96 in
Trailer Tire:Good Year Super H.-Miler 10.00-20
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)


Task Three: a) Tires Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE (θ)
IH 4 Spring Tractor, Reyco Trailer 96 in
Trailer Tire: Good Year Super Hi-Miler 10.00-20
---Tractor Drive Axles Load(High Side)
——Tractor Drive Axles Load(Low Side)

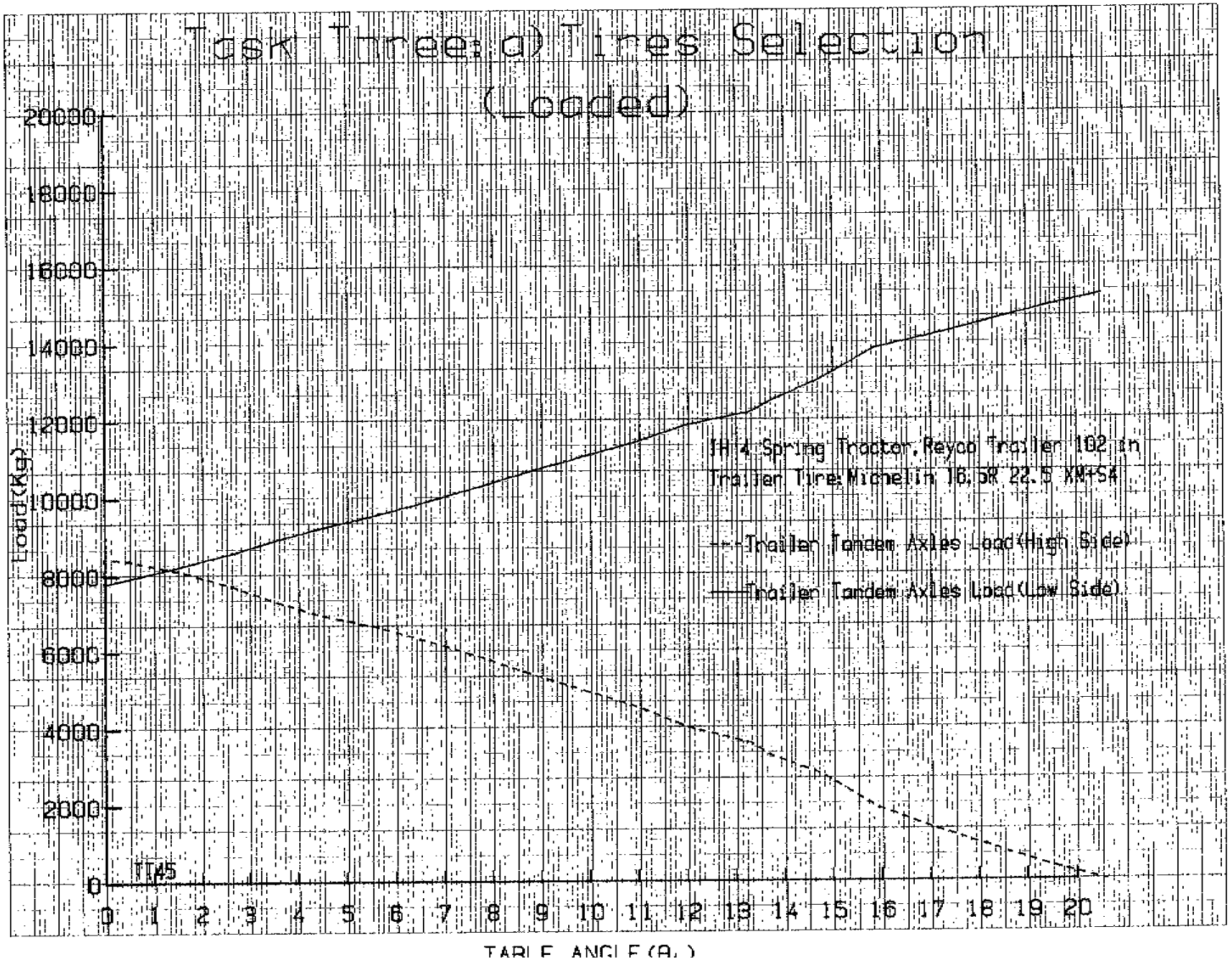

Task Three: a) Tires selection
(Unroad)
TH-4 Springs Tractor,Reyce Trailer 96 in
Trailer Tire:Good Year Super Hi-Miler 10.00-20
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(KN)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
TABLE ANGLE (θ.)

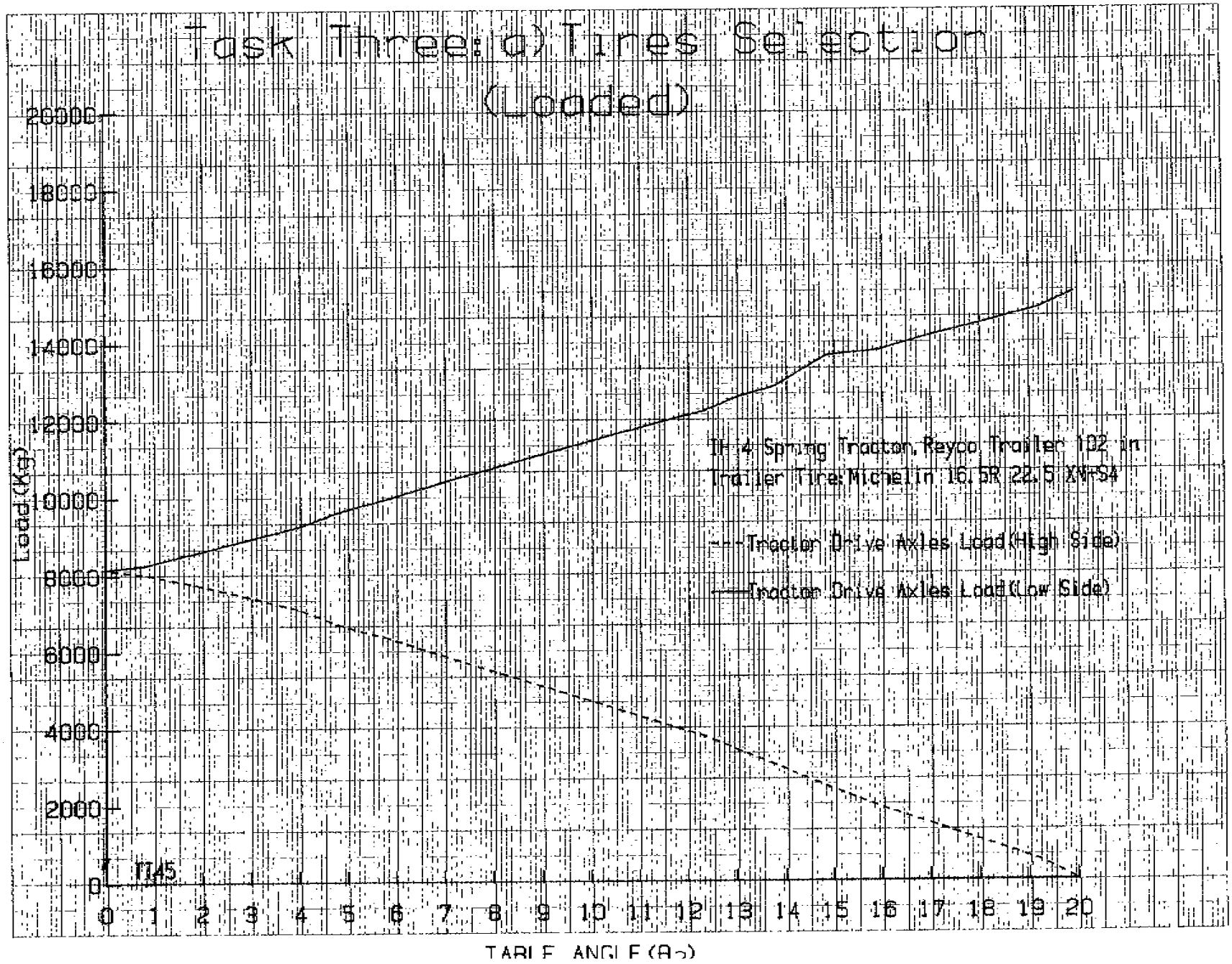

Task Three(3) Tires Selection
(Loaded)
JH 4 Springs Tractor, Reyco Trailer 38 in
Trailer Tire: Good Year Super Hi-Miler 10.00-20
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1137
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TARI E ANGLE (θ2)

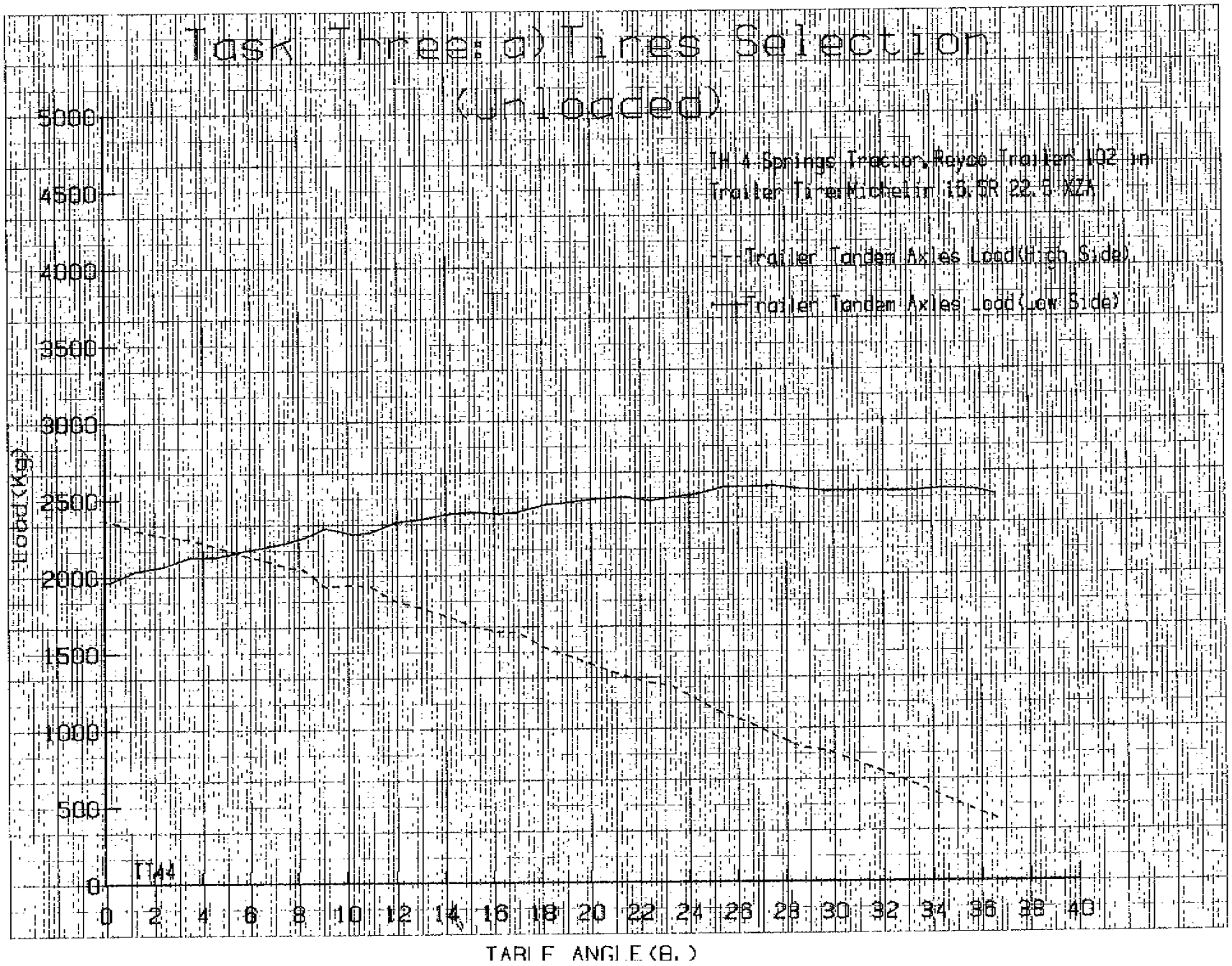
Task Three:a)Tires Selection

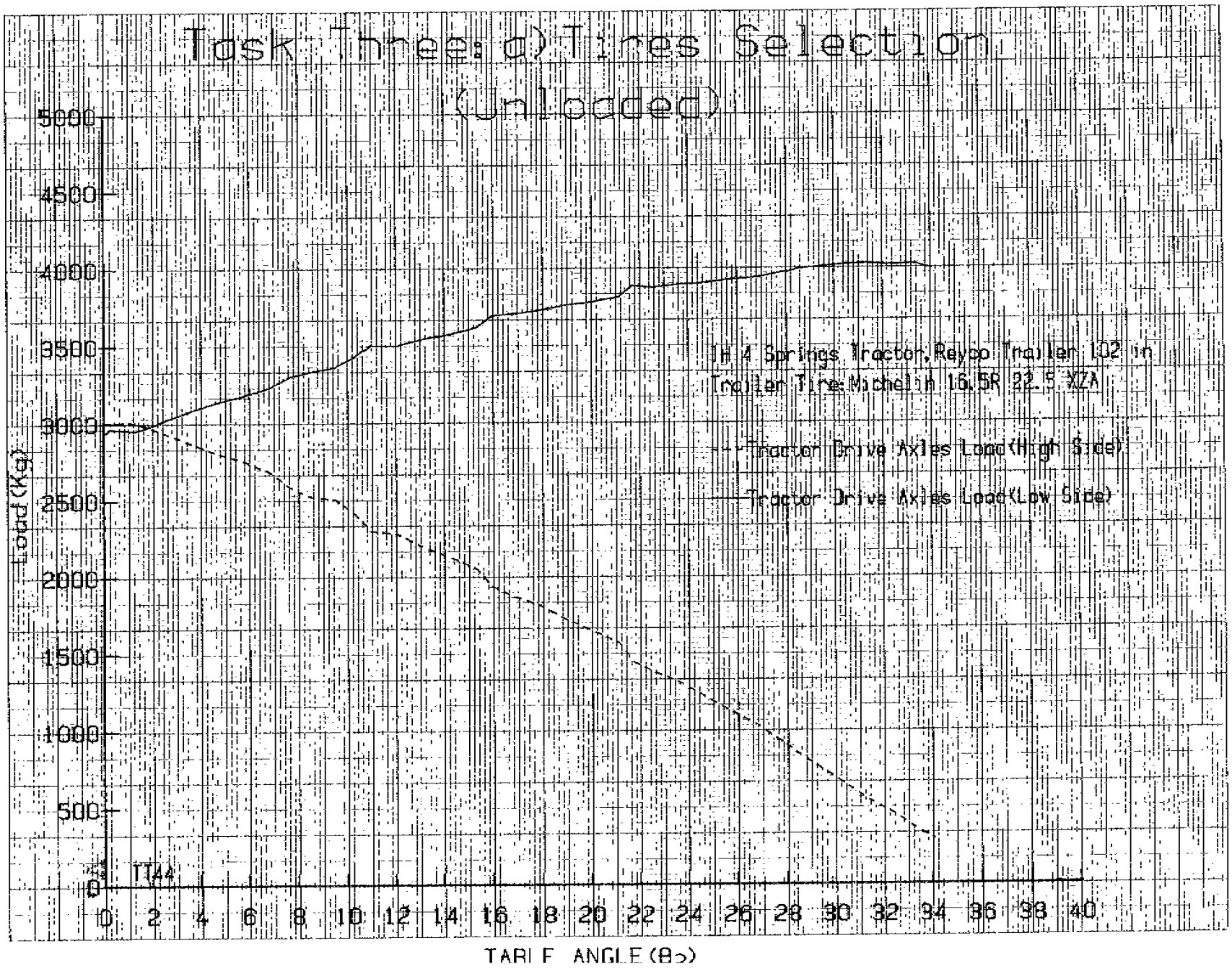
DESCRIPTION

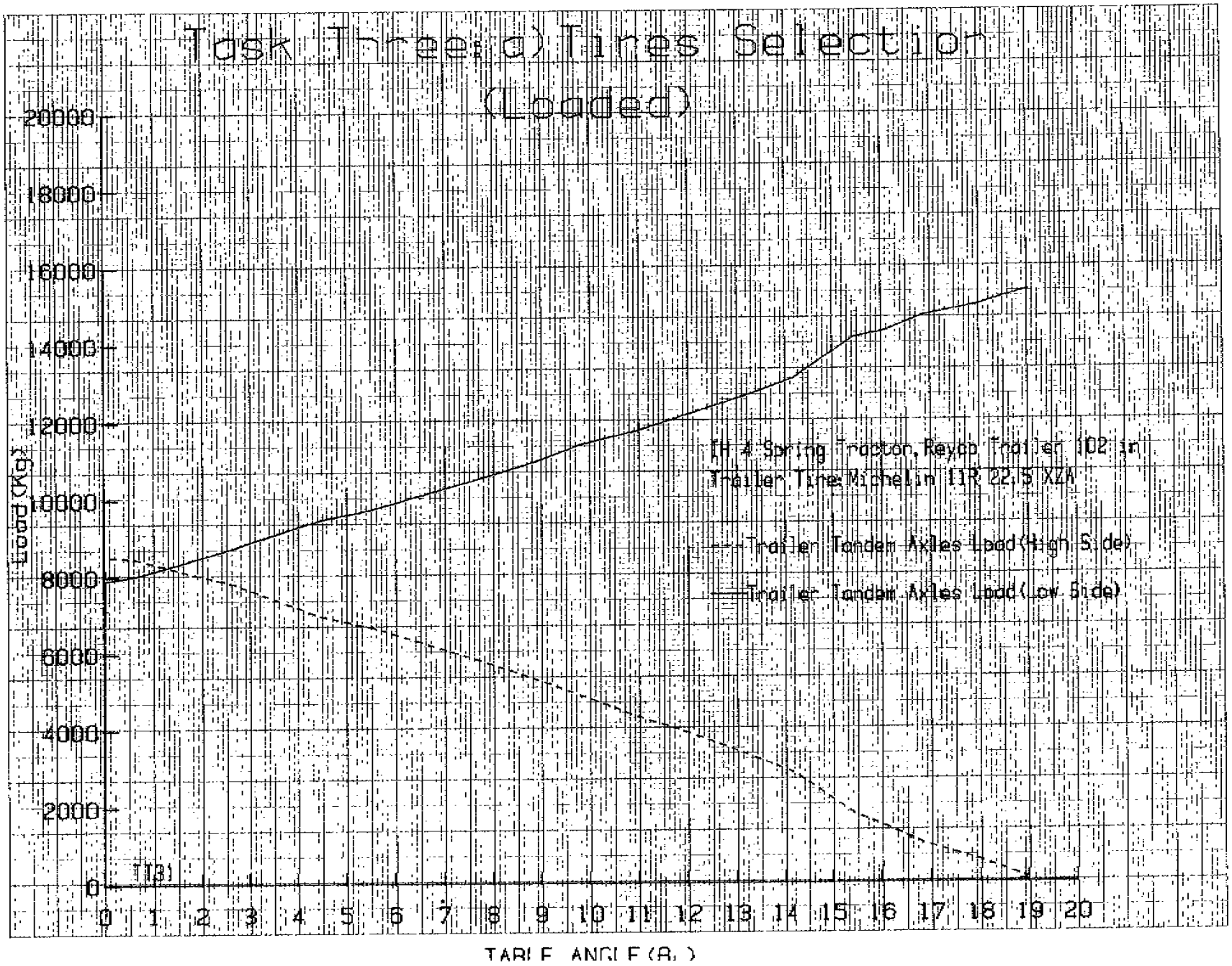
TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,72M
TRAILER LENGTH	14,78M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	IH 4 Springs
SUSPENSION TYPE ON TRAILER	Reyco 21B
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,70M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,51M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

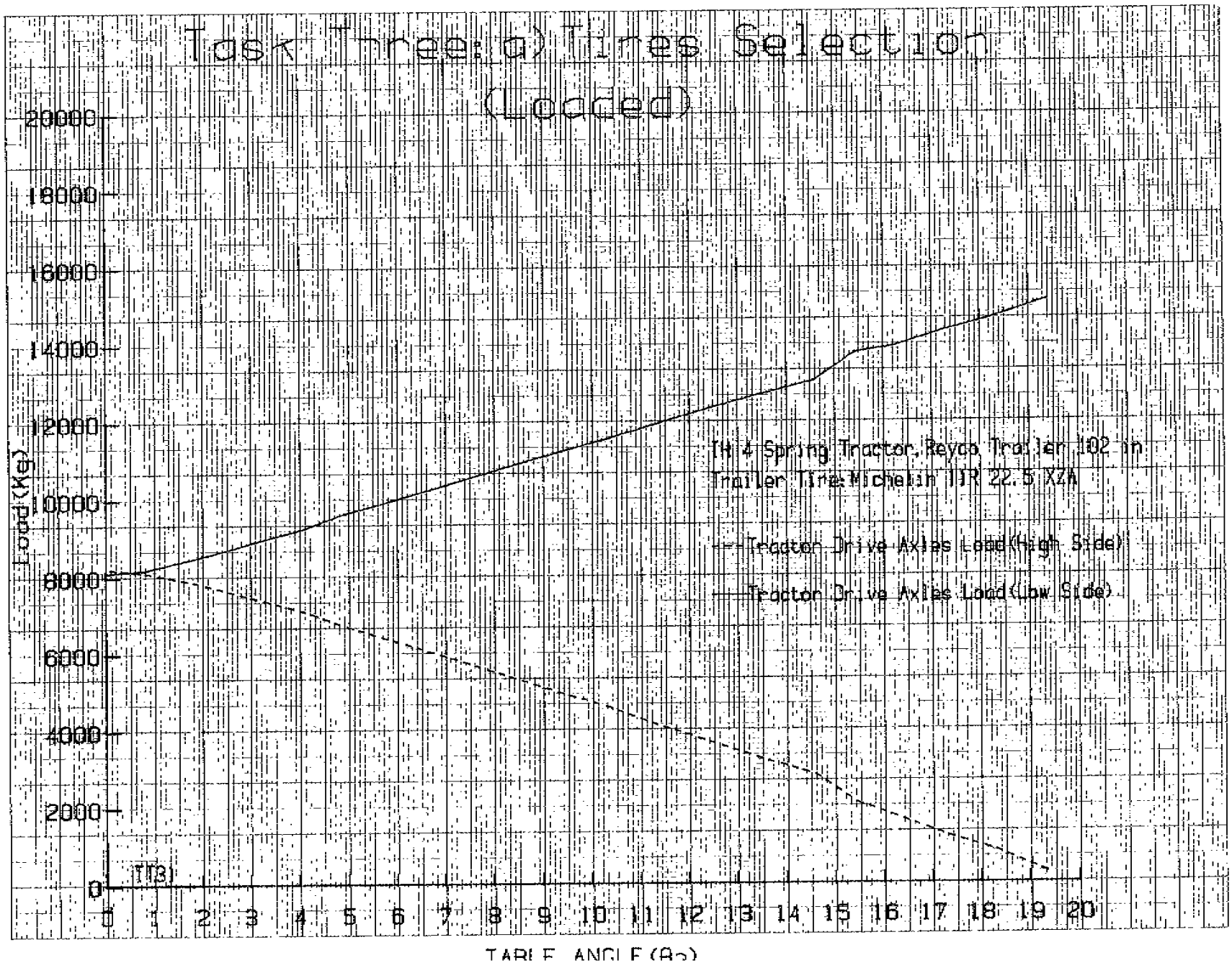


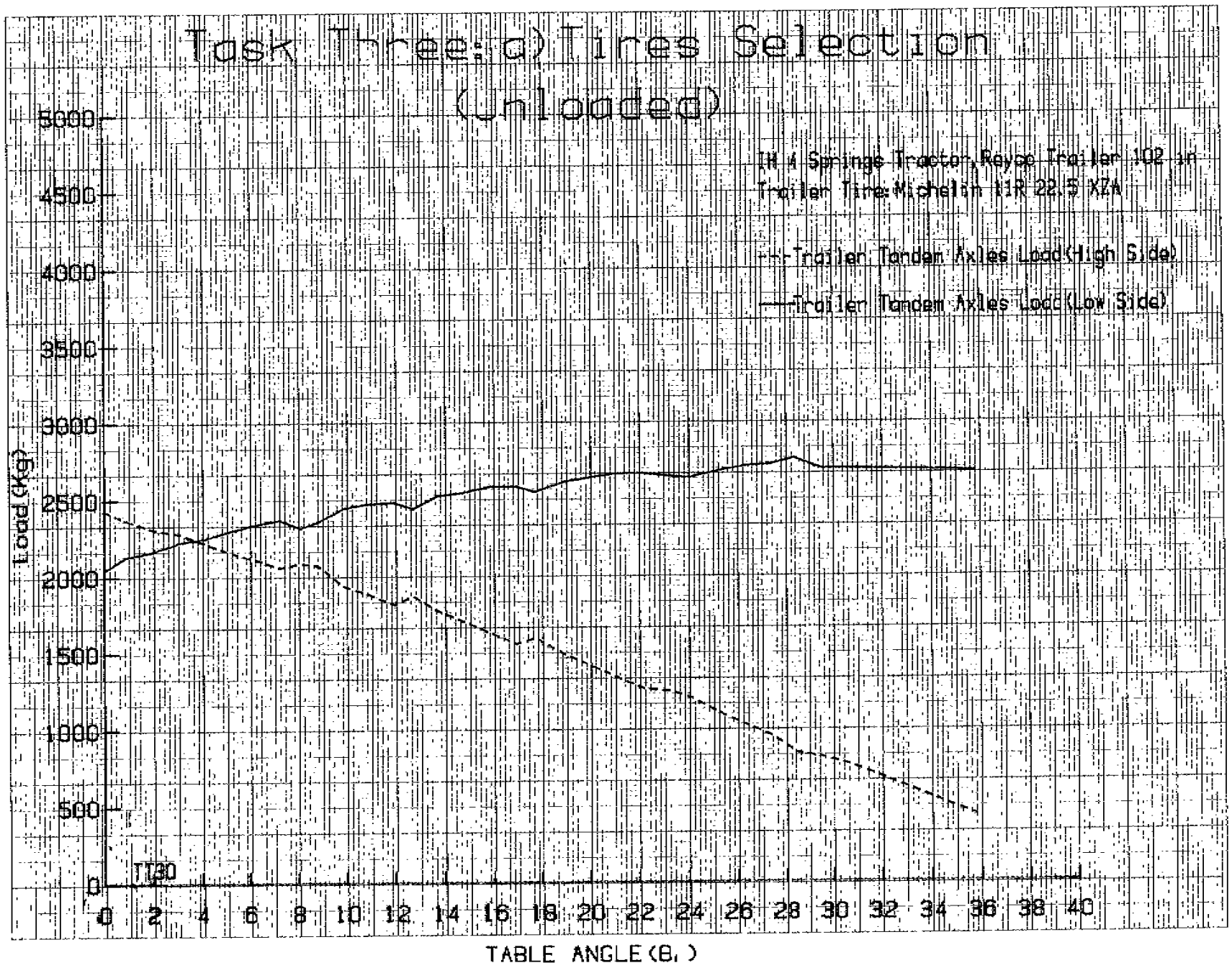

Task Three: a) Tires Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TH 4 Spring Tractor, Reyco Trailer 102 in
Trailer Tire:Michelin 16.5R 22.5 XW-S4
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

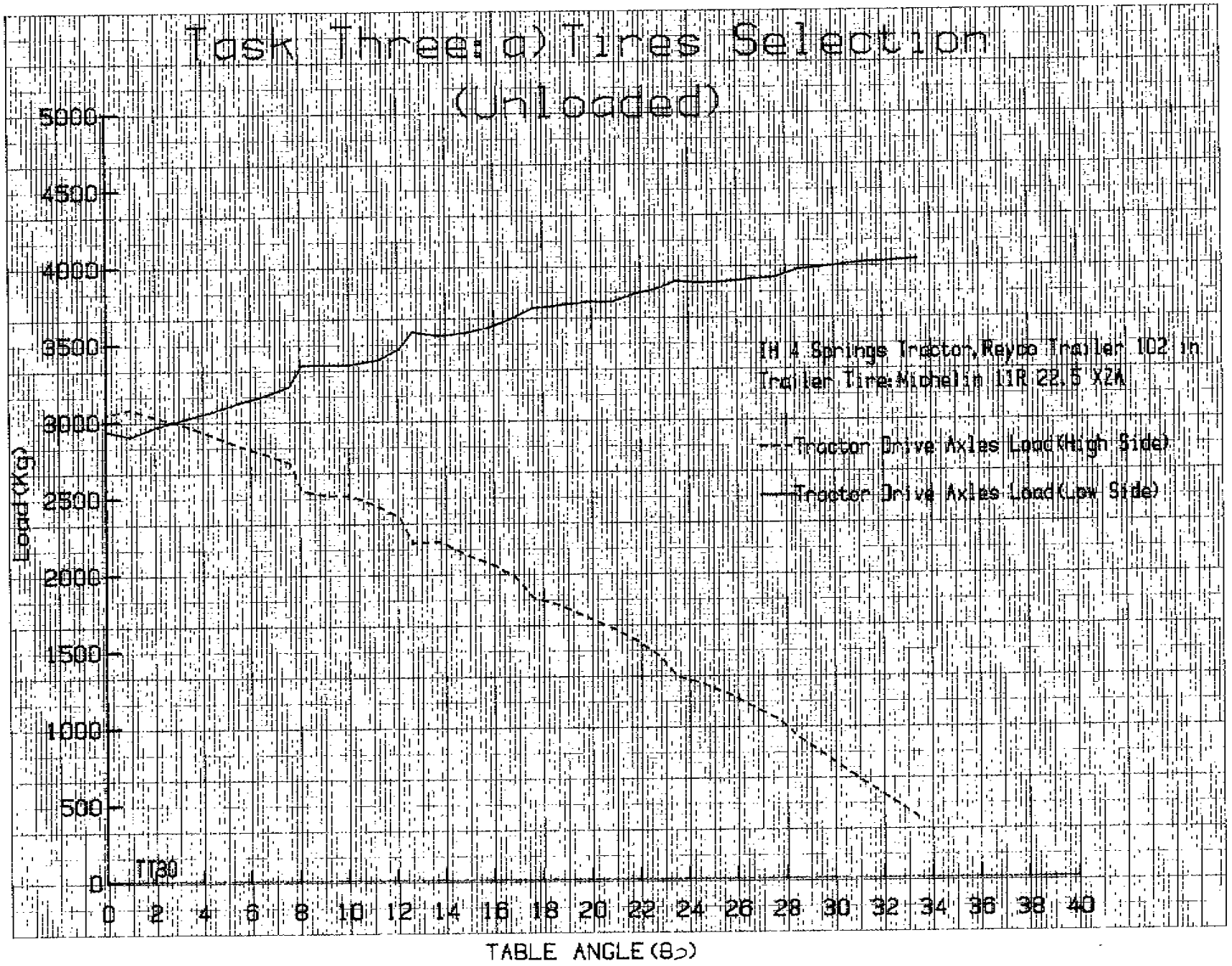

Task Three a) Tires selection
(Un-loaded)
TM 4 Springs Tractor, Reyco Trailer 102 in
Trailer Tire: Michelin 15.5R 22.5 XZA
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TIA4
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ,)

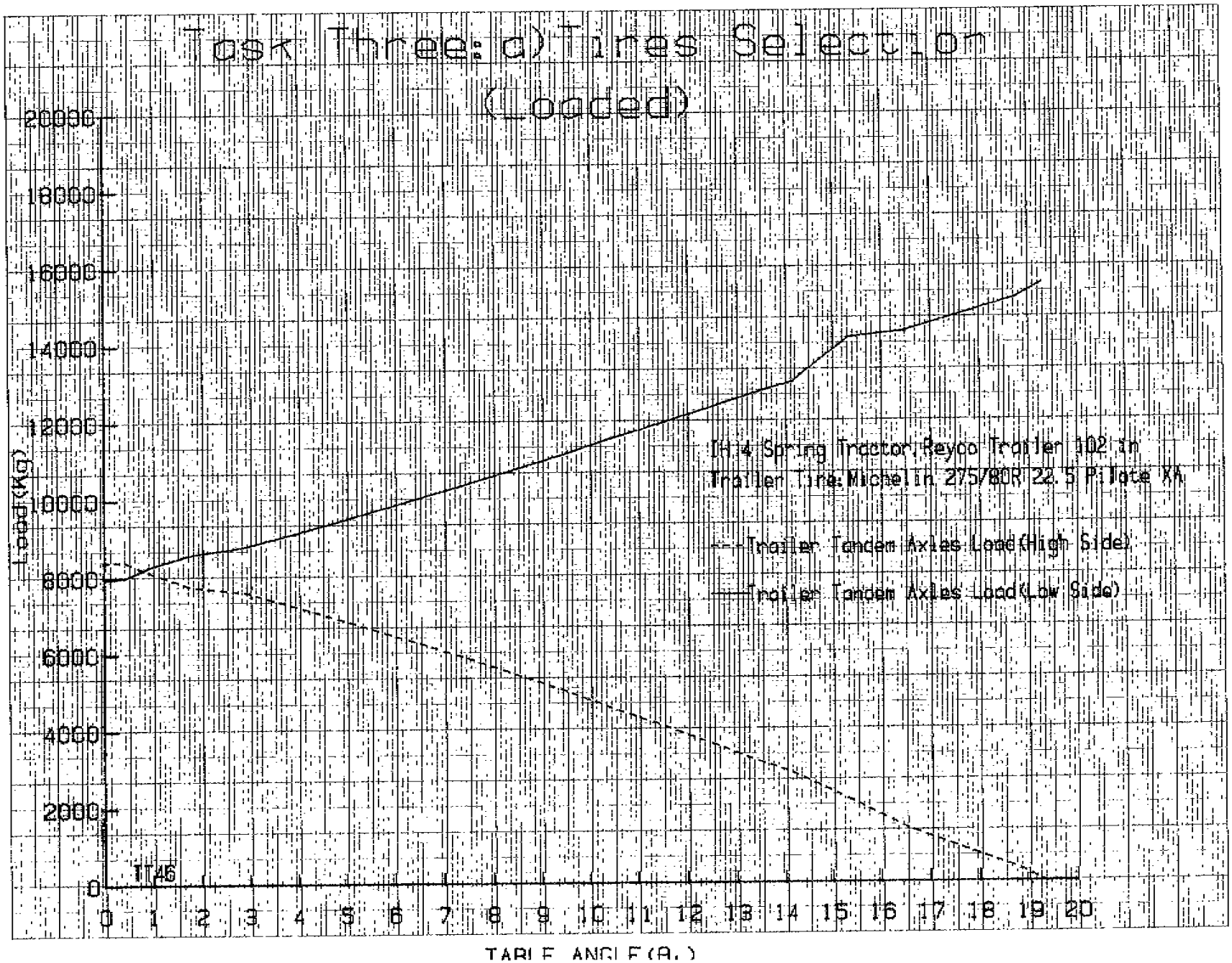


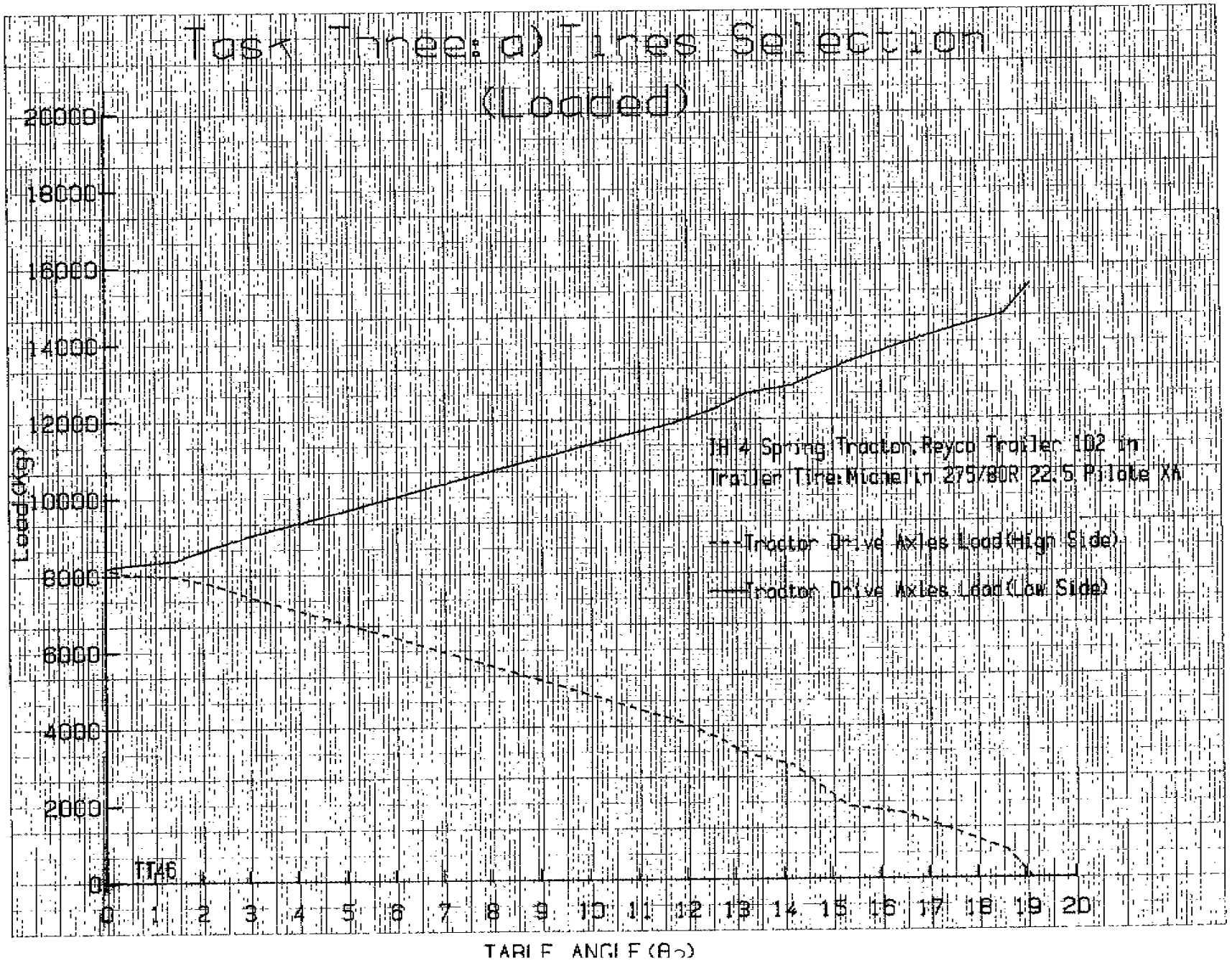

Task Three: a) Tires Selection
(Loaded)
Load (Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TAPE ANGLE (A,)
(T3)
IH 4 Spring Tractor, Reyco Trailer 102 in
Trailer Tire: Michelin 11R 22.5 XZA
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)

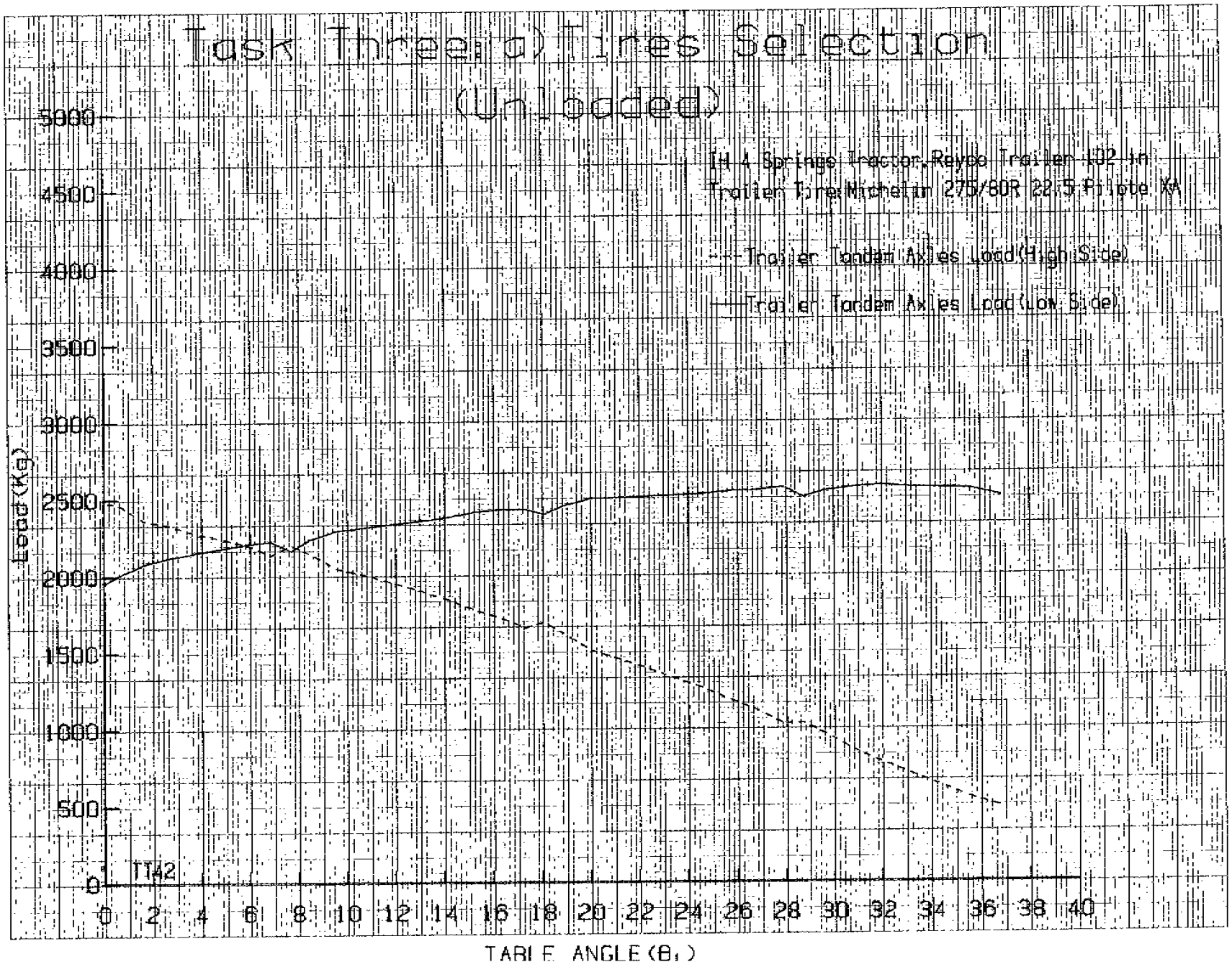


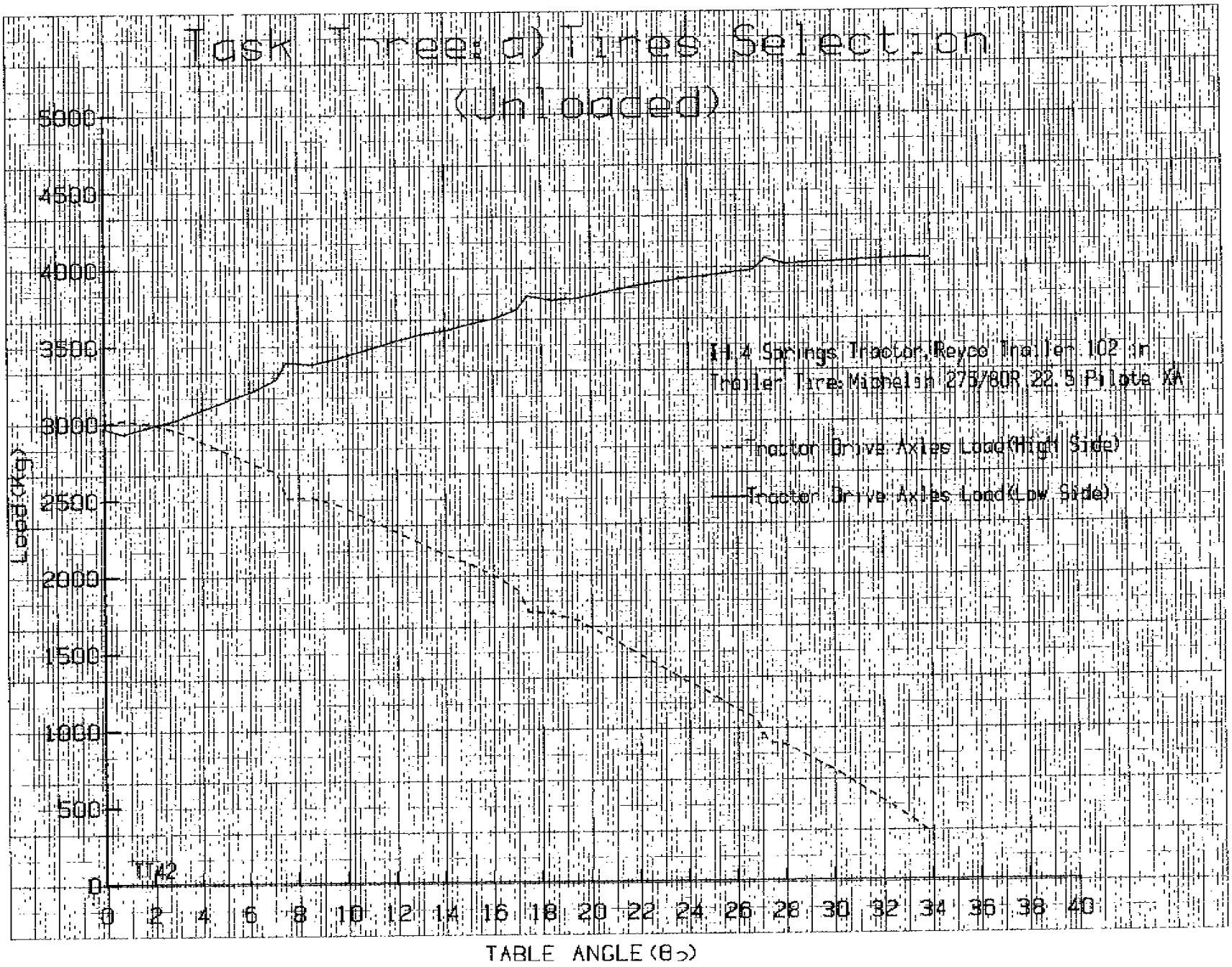


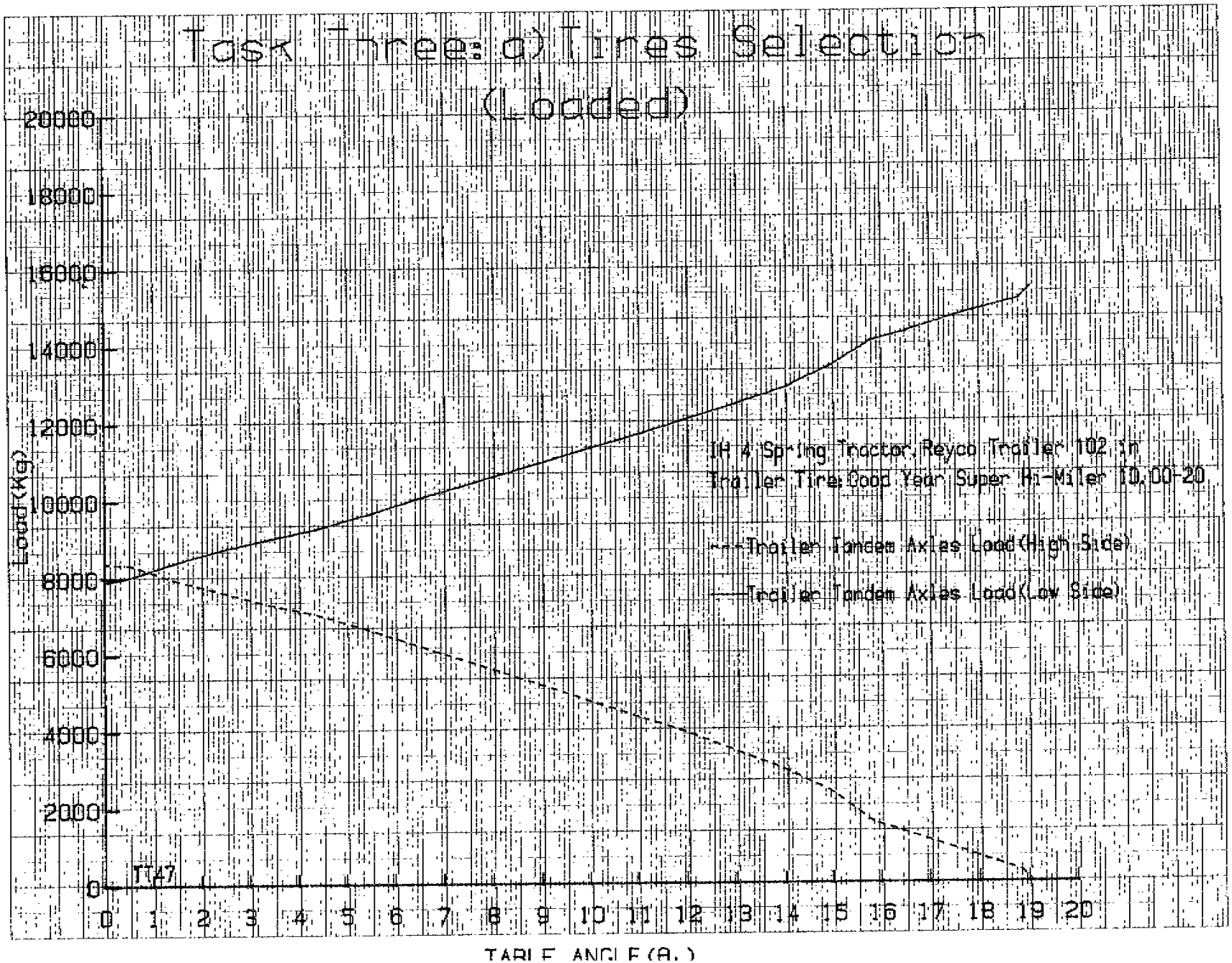


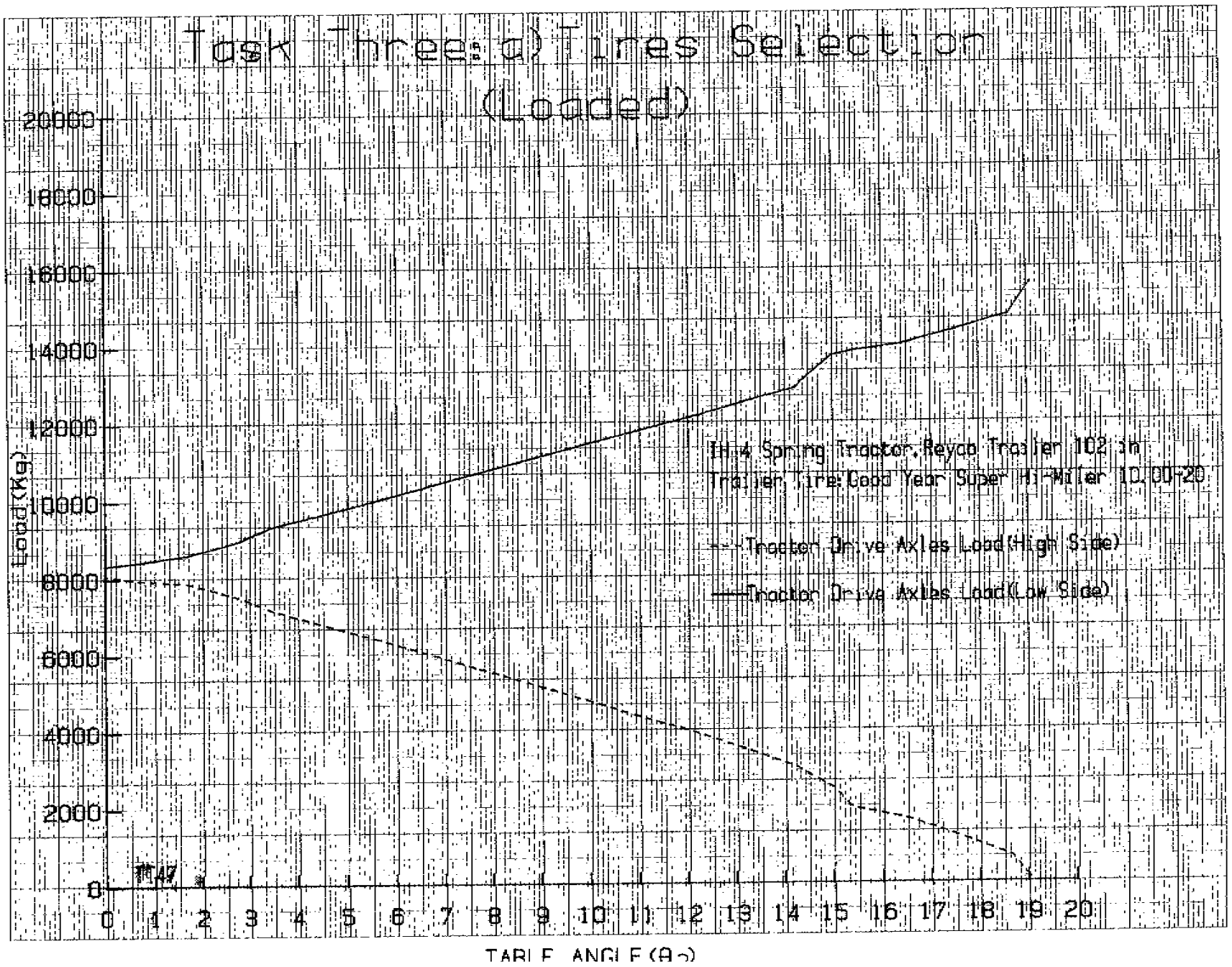

Task Three a) Tires Selector
(Loaded)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE(A.)
IH 4 Spring Tractor,Reyco Trailer 102 in
Trailer Tire:Michelin 275/80R 22.5 Pilote XA
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)

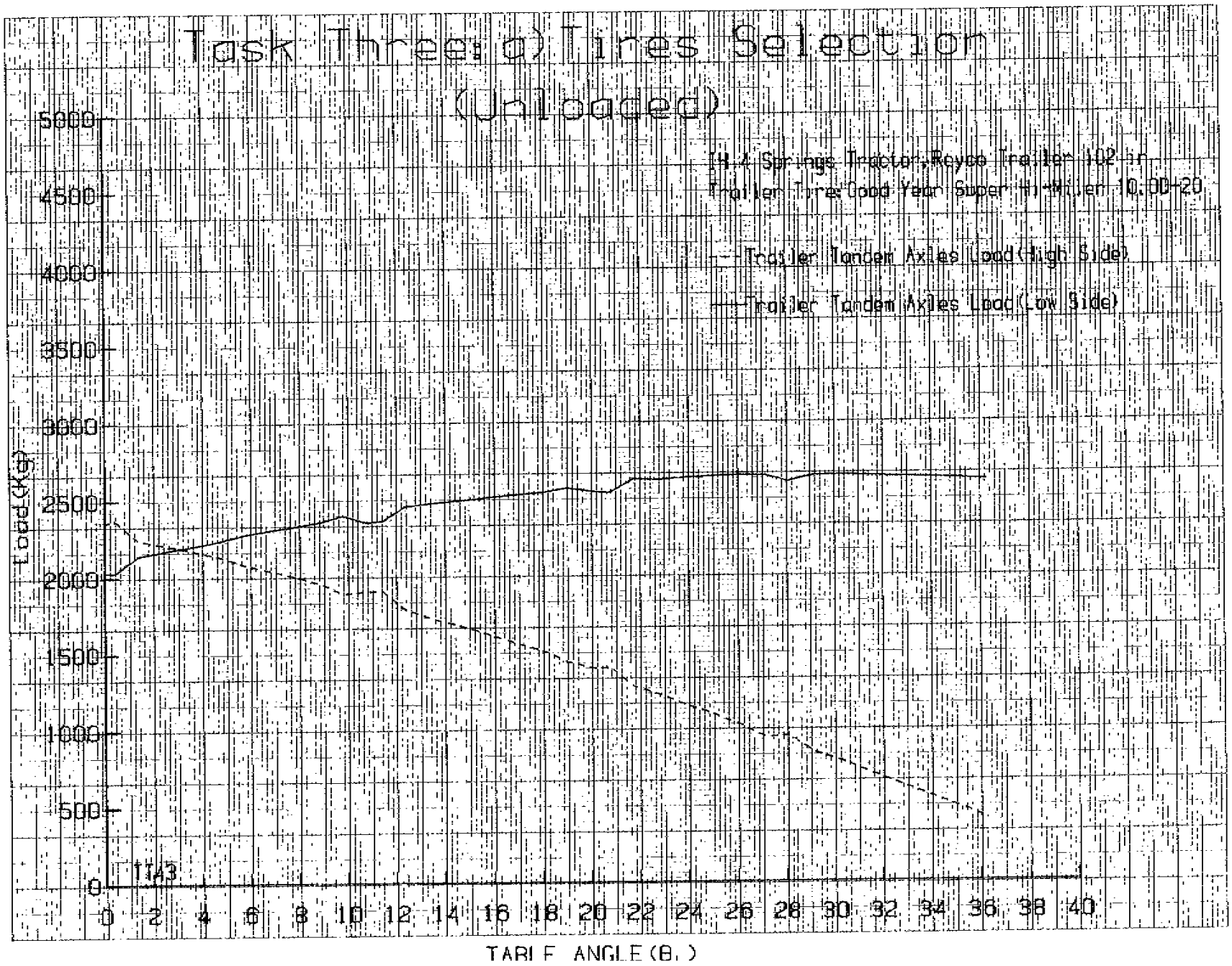


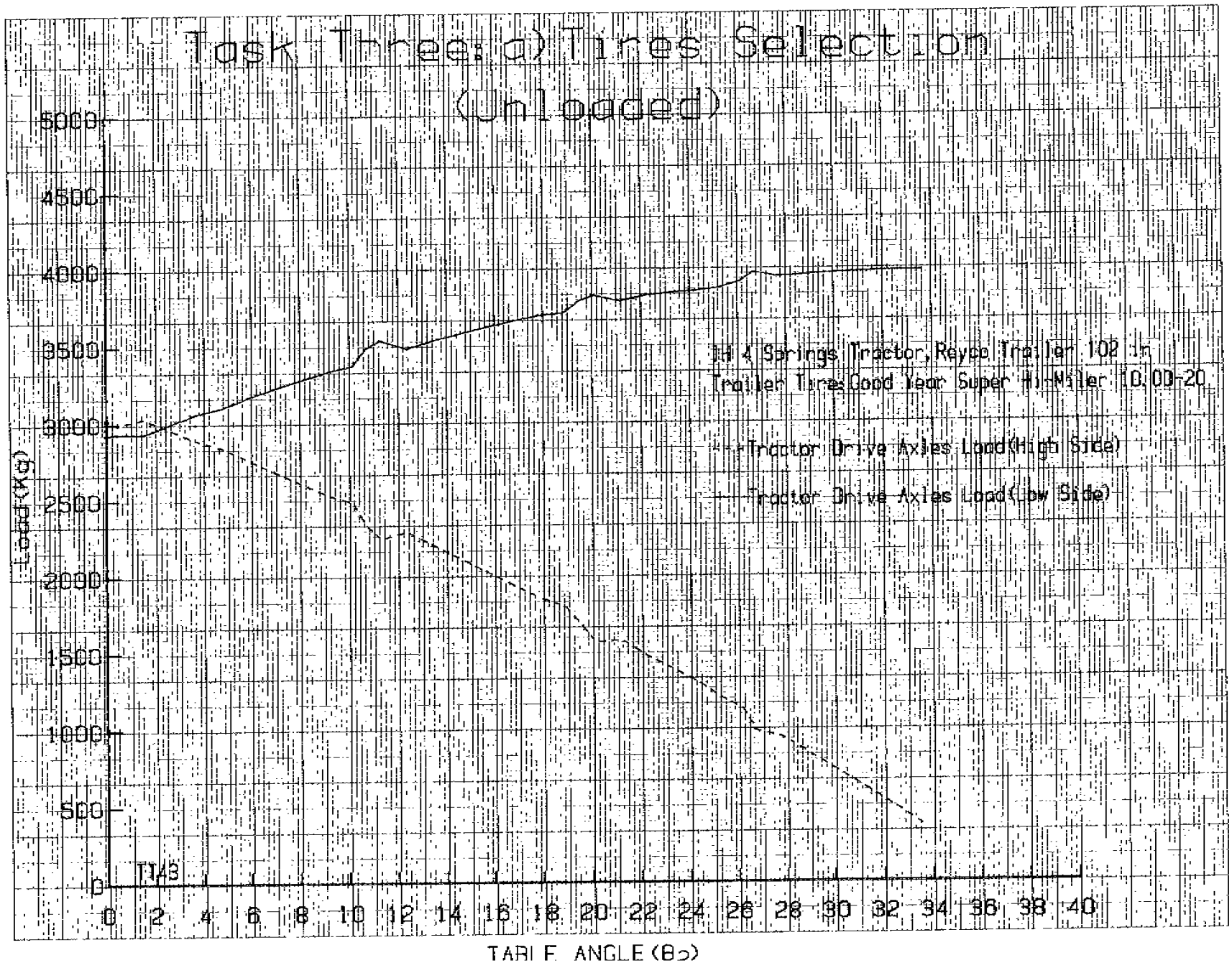

Task Three a) tires selection
(unloaded)
TH 4 Springs Tractor, Reyco Trailer 102 in
Trailer Tire: Michelin 275/80R 22.5 Pilote XA
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT42
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ1)


Task Three: a) Tires Selection
(Unloaded)
IH 2 Springs Tractor, Reyco Trailer 102 in
Trailer Tire: Michelin 275/80R 22.5 Pilote XA
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)
Load (kg)
TABLE ANGLE (θ)
TT#2
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40


Task Three a) Tires Selection
(Loaded)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
T47
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE(A.)
IH 4 Spring Tractor, Reyco Trailer 102 in
Trailer Tire: Good Year Super Hi-Miler 10.00-20
---Trailer Tandem Axles Load(High Side)
——Trailer Tandem Axles Load(Low Side)


Task threads lines selection
(Loaded)
Load(Kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TH-4 Spring Tractor,Reyco Trailer 102 in
Trailer Tire:Good Year Super Hi-Miler 10.00-20
Tractor Drive Axles Load(High Side)
Tractor Drive Axles Load(Low Side)

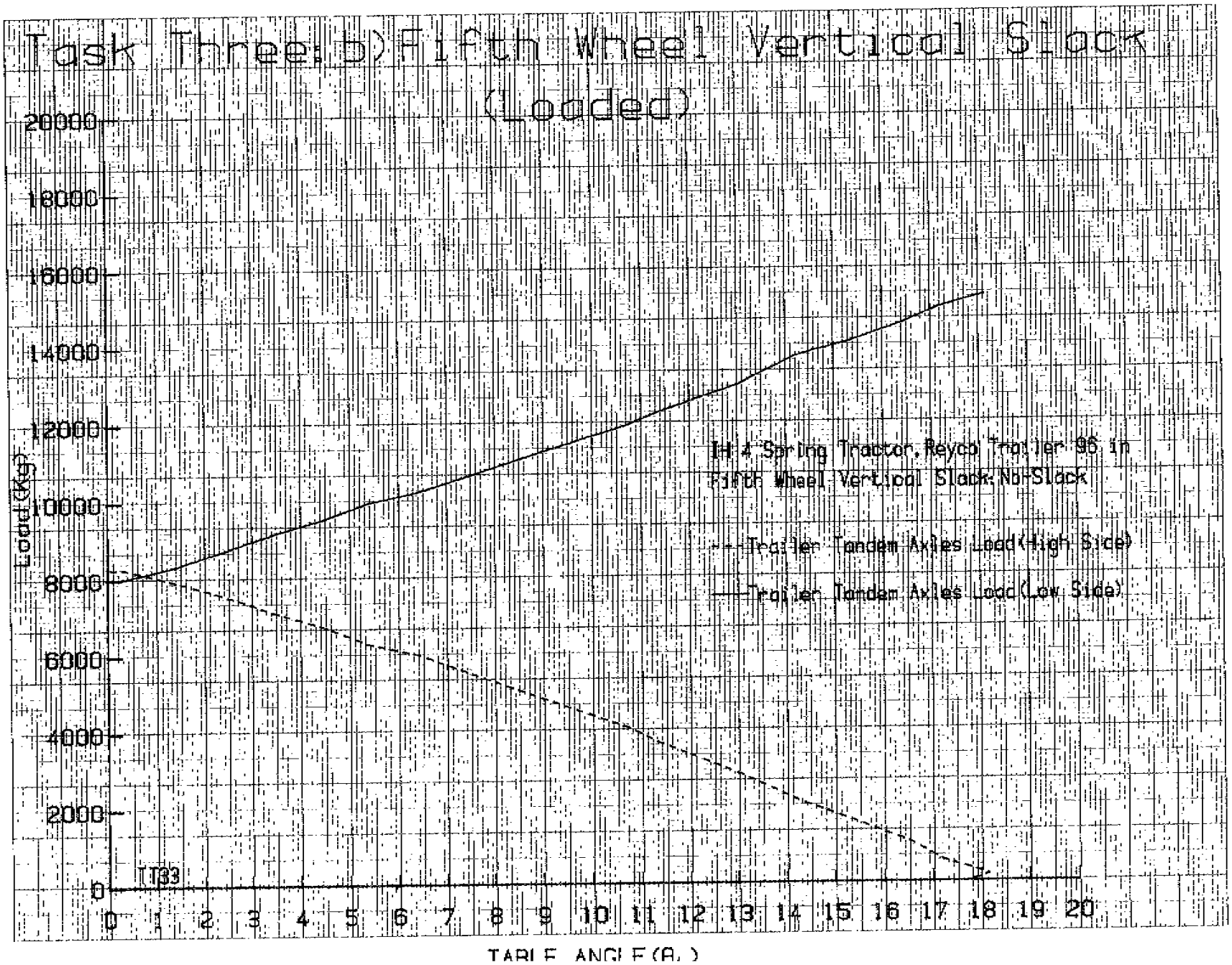

Task Three: a) Tires Selection
(Unloaded)
14.4 Springs Tractor, Reyco Trailer 102 in
Trailer Tire: Good Year Super Hi-Miler 10.00-20
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1143
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(θ.)

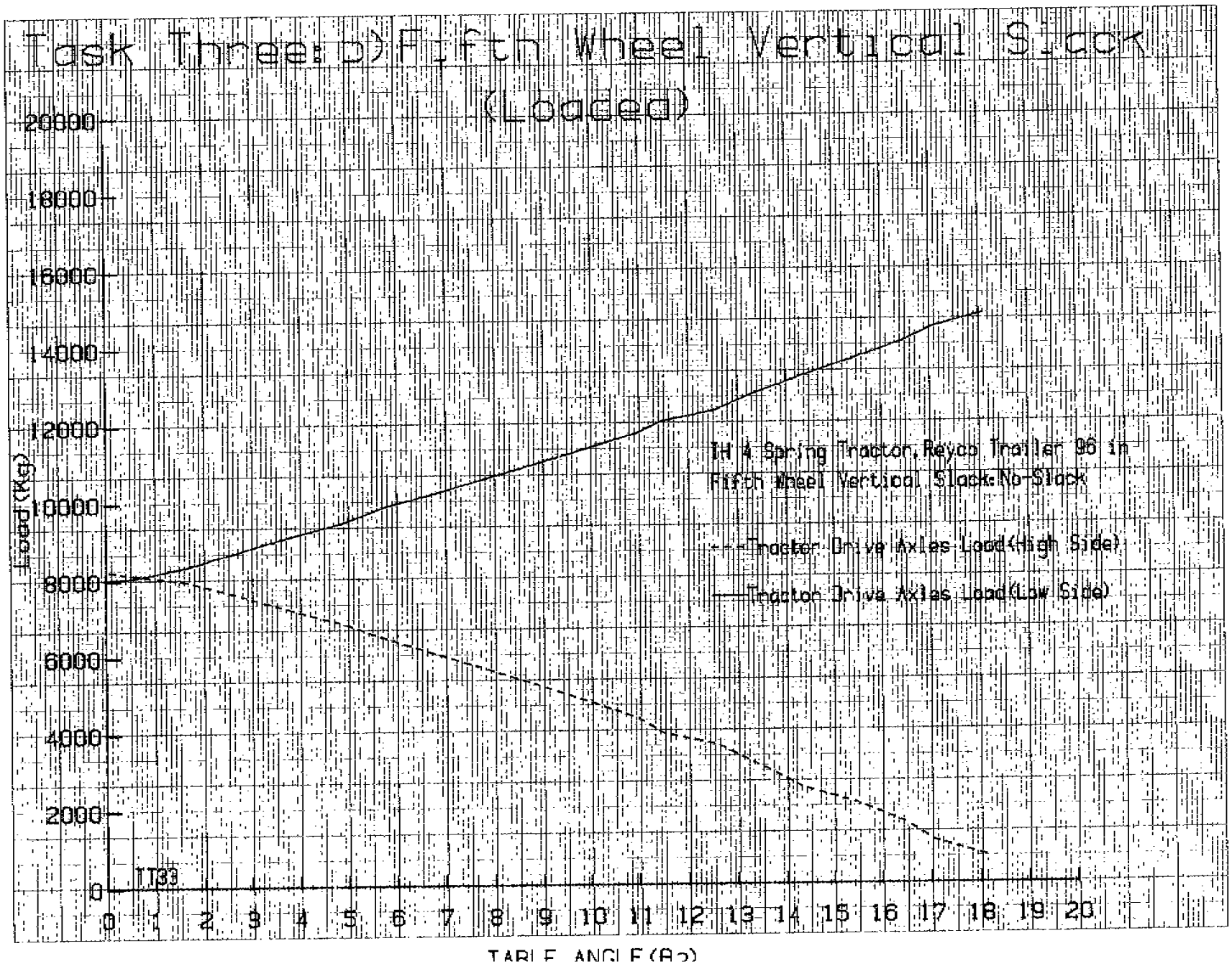


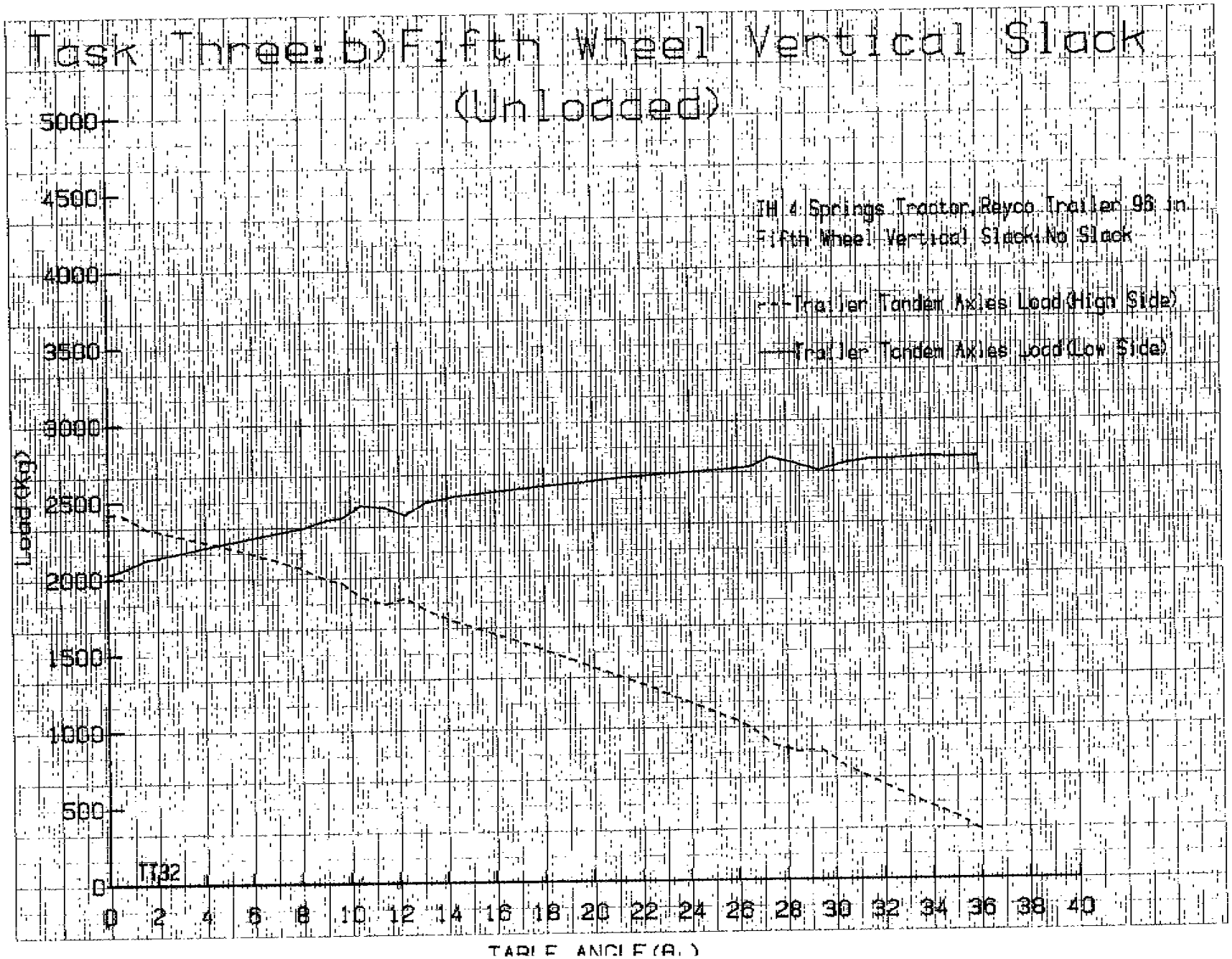
Fast Three:b)Fifth Wheel Vertical Slack

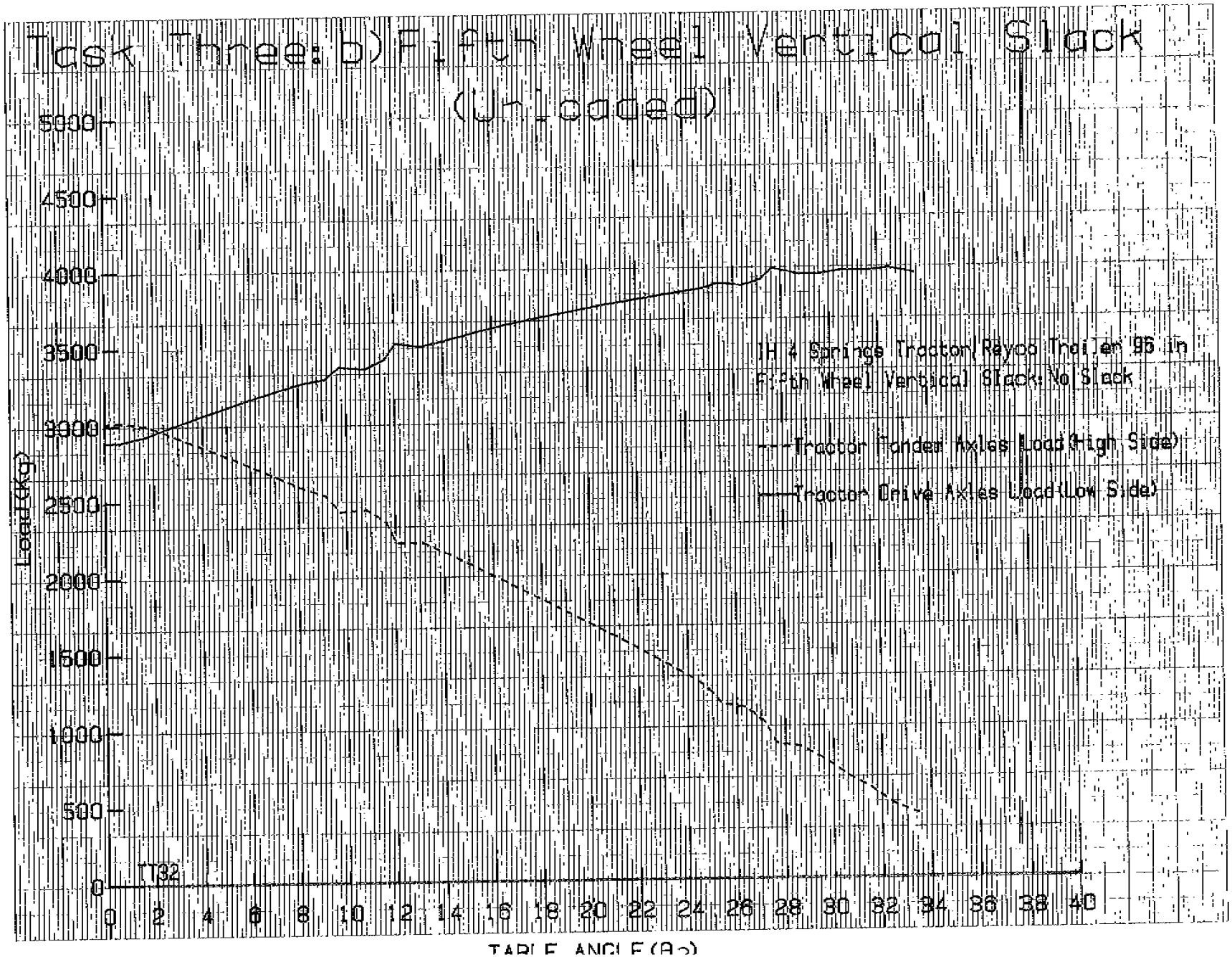
DESCRIPTION

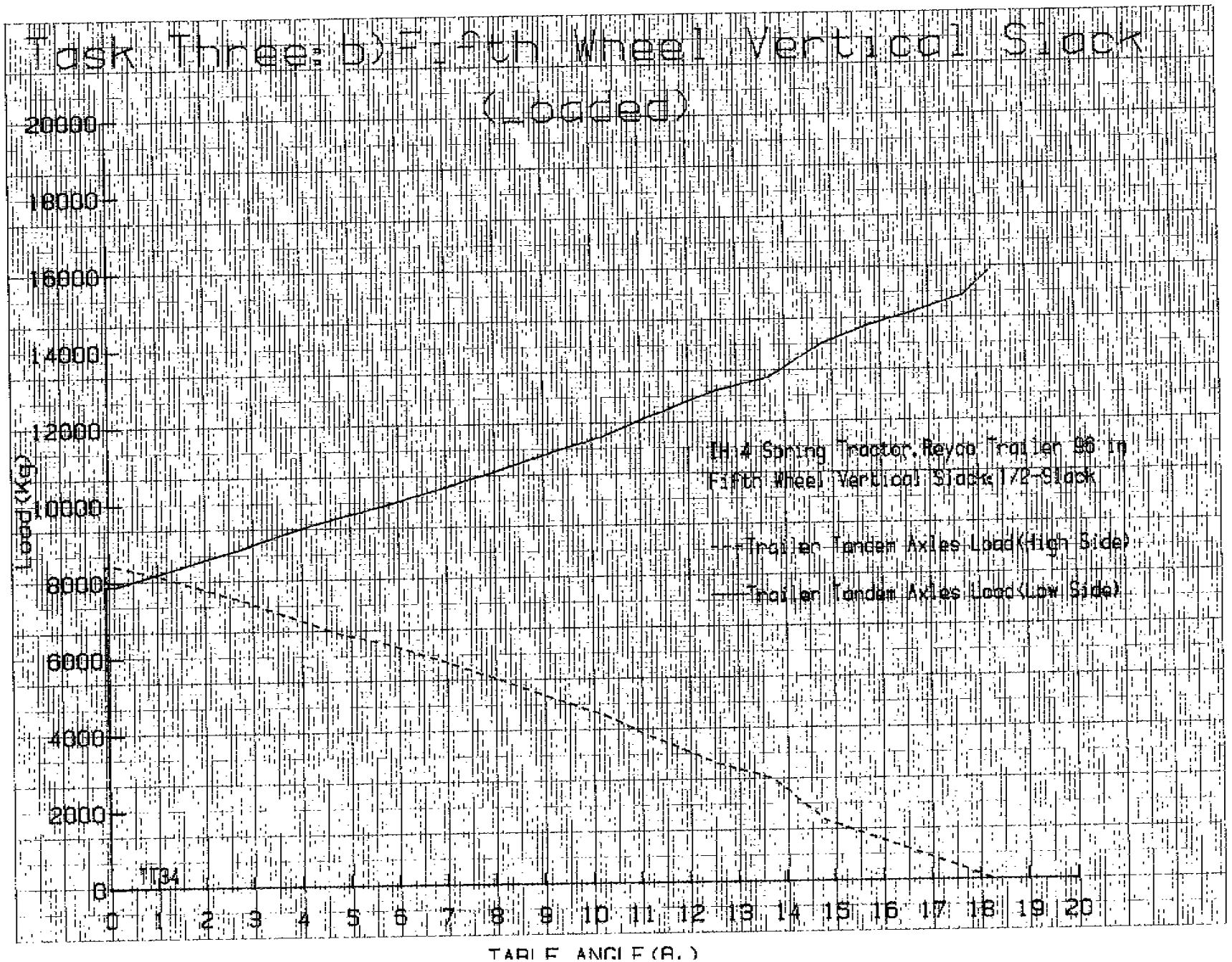
TRACTOR TYPE	Inter F-9370
TRAILER TYPE	14,78M Flat Bed
TRACTOR LENGTH	7,72M
TRAILER LENGTH	14,78M
TIRE TYPE ON TRACTOR	Michelin Radial 11R 22.5 XZA
SUSPENSION TYPE ON TRACTOR	1H 4 Springs
SUSPENSION TYPE ON TRAILER	Reyco 21B
AXLE SPREAD ON TRACTOR	4,96M 1,32M
AXLE SPREAD ON TRAILER	1,70M
TRACK WIDTH ON TRACTOR	2,37M
TRACK WIDTH ON TRAILER	2,35M
TIRE PRESSURE ADJUSTED TO	100 Psi
HEIGTH OF THE FIFTH WHEEL	1,22M
AMBIENT TEMPERATURE	10°c

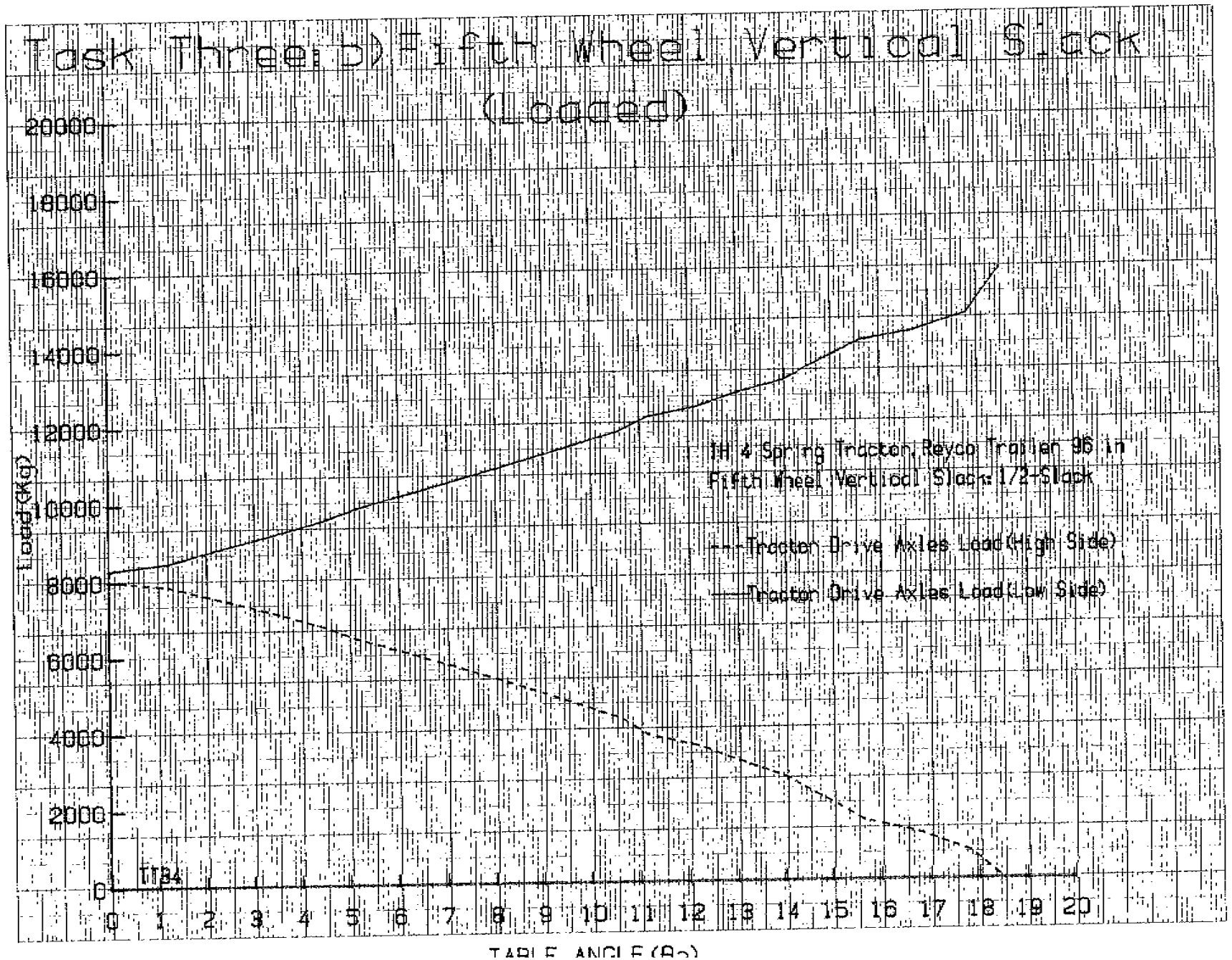


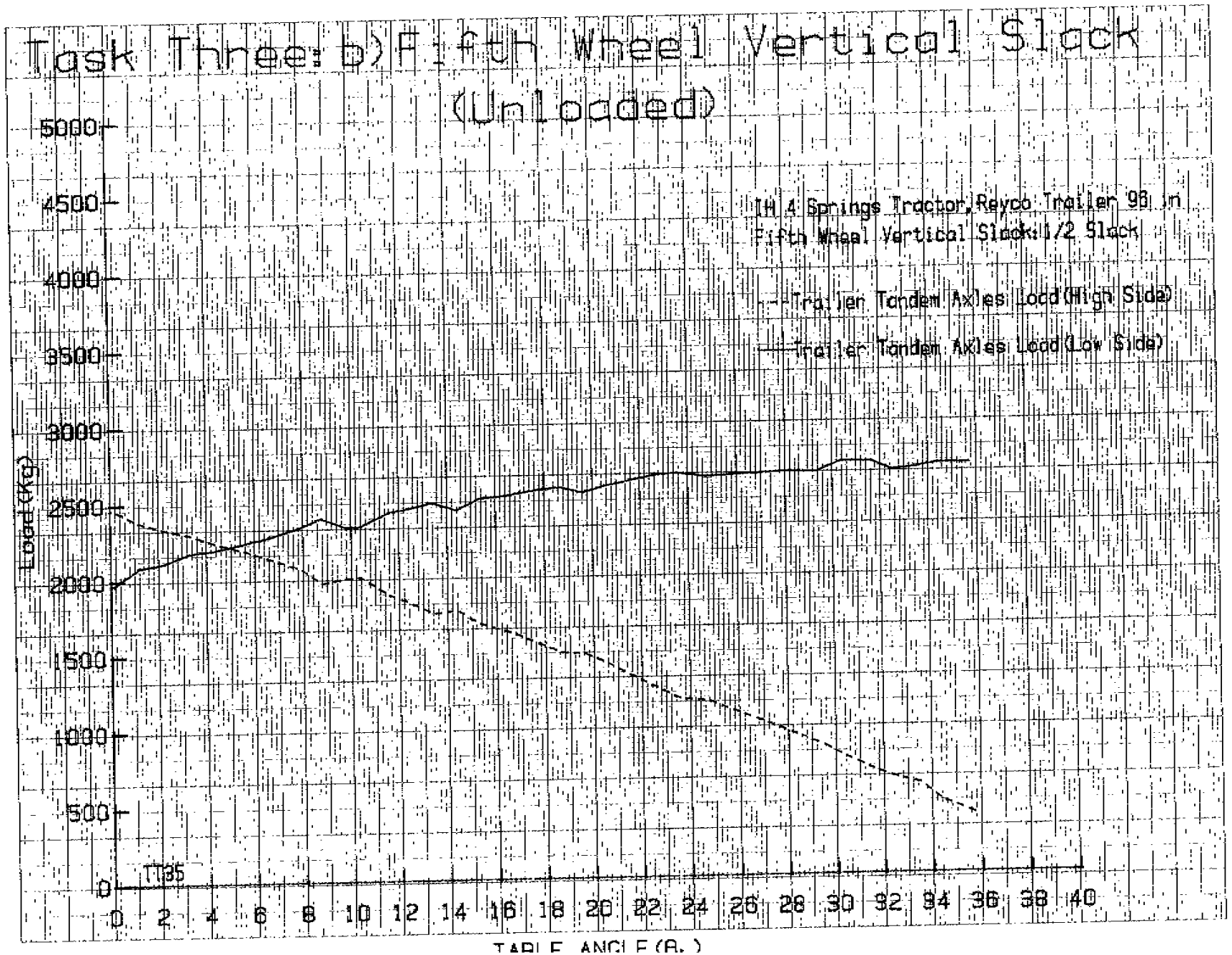



Task Three: b) Fifth Wheel Vertical Slack
(UnLoaded)
IH 4 Springs Tractor,Reyco Trailer 96 in
Fifth Wheel Vertical Slack,No Slack
Trailer Tandem Axles Load(High Side)
Trailer Tandem Axles Load(Low Side)
Load(Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
TT32
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE(A.)


Task three: b) Fifth wheel Vertical Slack
(Unloaded)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
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(Ao)
1H 4 Springs Tractor/Reyco Trailer 95 in
Fifth Wheel Vertical Slack: No Slack
Tractor Tandem Axles Load(High Side)
Tractor Drive Axles Load(Low Side)


Task Three: b) Fifth Wheel Vertical Slack
(Loaded)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Load(Kg)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TH # Spring Tractor, Reyco Trailer 86 in
Fifth Wheel Vertical Slack 1/2-Slack
---Trailer Tandem Axles Load(High Side)
——Trailer Tandem Axles Load(Low Side)


Task Three: D) Fifth Wheel Vertical Slack
(Loaded)
Load(kg)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
TT84
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TABLE ANGLE(θ2)
IH 4 Spring Tractor, Reyco Trailer 96 in
Fifth Wheel Vertical Slack: 1/2-Slack
---Tractor Drive Axles Load(High Side)
——Tractor Drive Axles Load(Low Side)


Task Three: b) Fifth Wheel Vertical Slack
(Unloaded)
IH 4 Springs Tractor, Reyco Trailer 98 in
Fifth Wheel Vertical Slack: 1/2 Slack
Trailer Tandem Axles Load (High Side)
Trailer Tandem Axles Load (Low Side)
Load (Kg)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1135
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
TABLE ANGLE (θ,)