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MOTION BASE SIMULATION TEST

OF THE M101A2 TRAILER

March 1991

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13. ABSTRACT *(Maximum 200 words)*
This report describes the testing of the M101A2 Trailer in the Physical Simulation Laboratory at TACOM. A motion base simulator was designed, assembled, and utilized to produce motion on the trailer. This motion represents typical terrain/speed scenerios encountered by trailers. The test plan executed followed the Comparison Product Test of the M101A2 trailer.

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Preface

This report presents the full-scale motion base simulation of an M101A2 trailer. Questions regarding motion base simulation of vehicles and/or components are to be referred to the U.S. Army Tank-Automotive Command, ATTN: System Simulation and Technology Division, AMSTA-RY, Warren, MI 48397-5000, Telephone: AUTOVON/DSN 786-6228, Commercial (313) 574-6228.

1.0 Introduction

This report, prepared by the System Simulation and Technology Division of the Directorate for Tank-Automotive Technology; U.S. Army Tank-Automotive Command (TACOM), describes the testing of the M101A2 3/4-ton trailer which was performed at TACOM's full-scale Physical Simulation Laboratory.

The purpose of this test was to conduct a Comparison Product Test (CPT) on the M101A2 trailer which is going to be manufactured by Kasel Manufacturing Company under contract DAAE07-89-C-1496. In addition, this test provided valuable test and comparison data for the modified M101 Turtle Mountain trailer which will soon undergo testing in the Physical Simulation Laboratory.

The M101A2 trailer was loaded with 1,500 pounds of dummy load to simulate the everyday average use. A motion base simulation test was then performed by the Analytical and Physical Simulation Branch (AMSTA-RYA) in the Physical Simulation Laboratory.

2.0 Item Description

The M101A2 trailer consists of an M116 frame supported by an axle assembly with leaf spring suspension upon which a Kasel cargo box is mounted. See Figure 1.

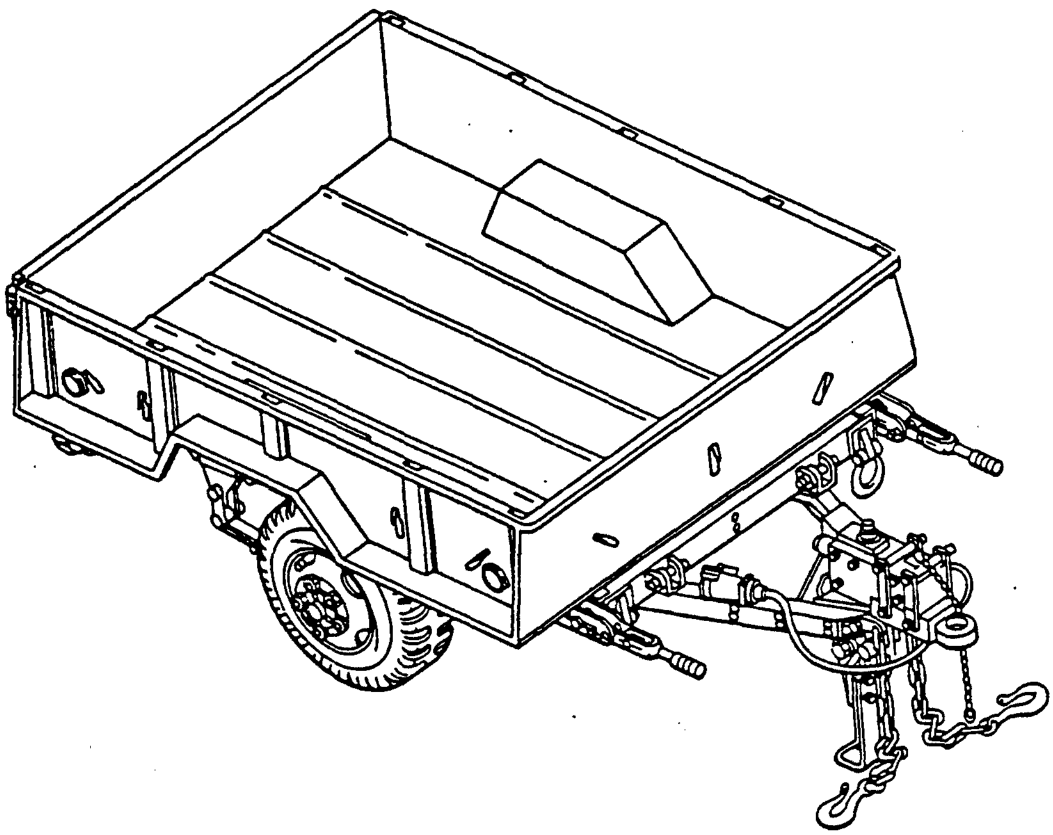
The suspension system has two leaf springs (five leaves per spring) and two automotive-type shock absorbers to provide proper ride characteristics and to absorb shock when traveling over different trails and cross-country roads.

Some technical data regarding weight and vertical and horizontal center of gravity position are presented in the Appendix.

3.0 Test Objective

The objective of this test was to effectively determine the durability of the M101A2 trailer when traveling over selected terrain profiles, as recommended by the 3,000 cross-country and secondary road miles in the Comparison Test Directive issued by the Light Tactical Vehicle Branch, at TACOM. In addition, the objectives were to validate the conversion concept and design modification changes, manufacturing methods, conformance to safety requirements, compliance with applicable military requirements, and to lay the grounds for the probable increase in payload weight limit.

In addition, this test provided valuable test data for concept evaluation, test methodology, and dynamic model verification, which was essential to the successful completion of the test.



M101A2 Trailer
Figure 1

4.0 Inspection

A visual inspection of the M101A2 trailer, prior to testing, was performed and did not reveal any major problem or malfunction of the M101A2 trailer.

During the test, the following inspections and tasks were accomplished as required by TM 9-2330-213-14-P.

Initial.

1) Lubricated and prepared vehicle according to TM 9-2330-213-14.
2) Set tire air pressure to 35 psi.
3) Performed visual inspection of vehicle and searched for cracks or any mechanical damage or abnormalities.

Ongoing.

1) Checked tire pressure every 300 miles.
2) Lubricated and checked approximately every 300 miles.
3) Visually inspected for cracks, abnormalities.
4) Performed simulator maintenance.
5) Checked payload.
6) Rotated tires every 300 miles.

5.0 Dummy-Load Dimensions

The dummy load was a steel plate with dimensions of 36 inch by 36 inch by 4 inch thick. It was placed on a 6-inch pallet.

6.0 Conclusions and Recommendations

There were no encountered problems serious enough to stop the test, although it was noticed that after 1,620 miles (570 miles of Churchville 6, 570 miles of Churchville 7, 480 miles of APG 37), the left leaf spring was sagging. At that time, measurements to determine the clearance between the jounce stop and frame were taken and are as follows:

Right side: 4.50 inch
Left side: 3.81 inch

The measurements were taken with a 1,500 pound dummy load symmetrically centered in the longitudinal and lateral axis above the axle. These measurements remained the same during the rest of the test.

Further inspections did not reveal any additional leaf spring degradation. The test was completed on March 1, 1991. The final inspection disclosed that the trailer and components had not sustained any damage during the 3,000-mile simulation test. It is recommended that some additional static and dynamic testing of the subject leaf springs be performed to prevent potential future problems. It should be noted that, throughout the test, the 1,500 pound dummy load was symmetrically distributed. If this load was shifted (off center) closer to the left spring, it is felt that the leaf spring would fail.

From the results of this test, it appears that this trailer should perform adequately throughout its mission scenario.

7.0 Discussion

7.1 Motion Simulator

7.1.1 Summary

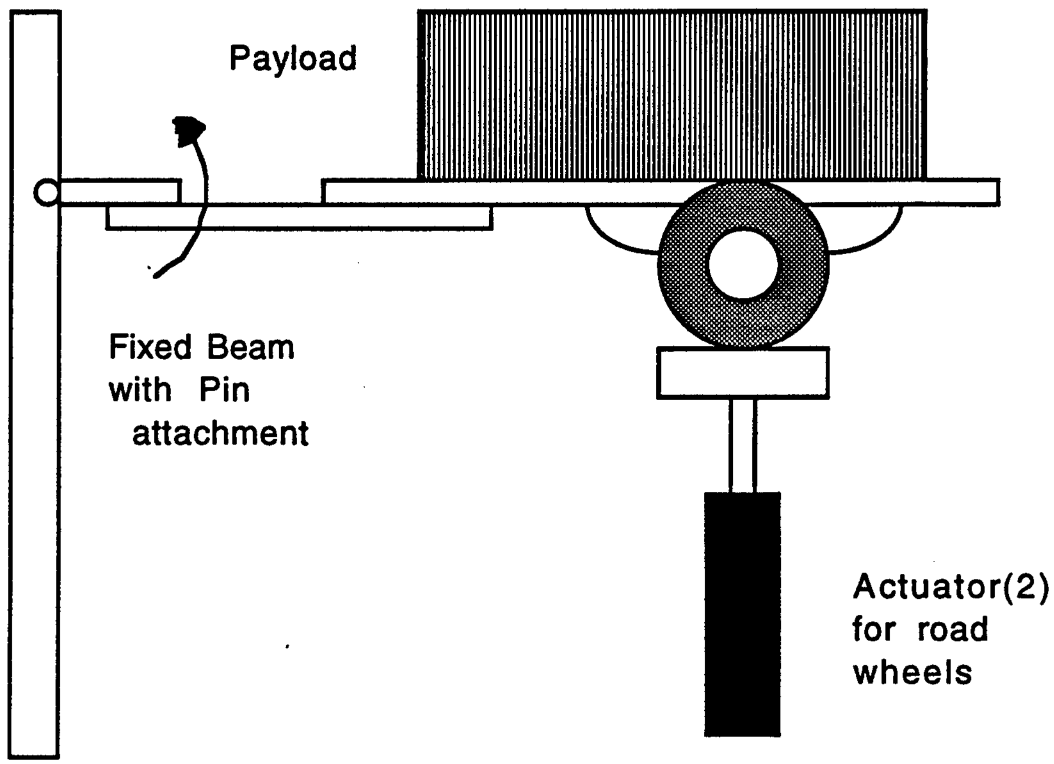
The motion simulator constructed for this test is a high-performance three-axis (roll, pitch, and vertical) simulator capable of testing any two-wheeled trailer. See Figure 2. The simulator uses electro-hydraulic actuators to produce motion on the test item. The simulator is controlled by an operator at a control console. The trailer tires rest on platens attached to each actuator. The lunette is attached to a fixed beam for safety.

Pitch is produced by the fact that the pintle attachment is stationary at the fixed beam, and the actuators produce a rotating (pitch) about the pintle. An analysis conducted by the Analytical and Physical Simulation Branch concluded that this simulator design is adequate for testing durability for this trailer, when subject to its mission scenario.

In operation, a Computer Automated Measurement and Control (CAMAC) system creates actuator commands which synergistically produce the vertical and rotational motion requirements. The CAMAC system is interfaced with the RDE Center Supercomputing Network and motion controllers that output a servo current drive signal to each actuator.

All simulator design, assembly, integration, and software development was accomplished within the RDE Center.

Pitch, Roll, Vertical Motion Simulator



Two-actuator simulator
Figure 2

7.1.2 Performance Specification

The performance envelope of the motion simulator is given in Table 1.

Table 1 Performance Summary of Simulator

Parameter	Value
Payload	1,500 pounds plus trailer
Axes	Roll, Pitch, and Vertical
Maximum excursions	
Vertical	+- 6 inches
Pitch	+- 5.7 degrees
Roll	+- 3.1 degrees
Maximum acceleration (actuator)	9 g's
Positional bandwidth	12 hertz

7.1.3 Simulator Control System

The control system is made up of the CAMAC system, servo controllers and servo valves ported to the actuators. TACOM engineers write software on the CAMAC system, which sends real-time, scaled actuator commands through four 12-bit digital-to-analog converters at a clock rate of 100 samples per second. The software is written such that actuator commands are provided continuously for 12 hours or more without replenishing the CAMAC system with additional road profile data.

These commands are received by two servo controllers which supply current signals to drive the servovalves on the actuators. They do this while maintaining actuator loop control.

7.2 Profile Selection

The motion simulator is supplied with actuator commands that reproduce the dynamic effects of a variety of secondary road and cross-country terrains. The Comparison Test Directive summarizes the mission profile for the M101A2. Courses and simulated speeds were selected from this library that match characteristics of those from the directive. These are specified in Table 2.

Table 2 Selected Courses

Course type	Bump max	Simulated Speed
Gravel		
- Churchville 6	1.8 inch pk-pk	25 mph
- Churchville 7	1.2 inch pk-pk	25 mph
Level Cross-Country		
- APG 37	4.4 inch pk-pk	18 mph
- Letourneau 5*	5.5 inch pk-pk	12 mph
Hilly Cross-Country		
- Letourneau 4*	3.5 inch pk-pk	15 mph
Belgian Block**		
- Churchville 7	1.2 inch pk-pk	25 mph

* Letourneau courses run were actually one-half amplitude of the original Letourneau courses profiled at Waterways Experiment Station, Vicksburg, Miss.
** Belgian block profile not available on computer. Churchville 7 was used instead.

Members of the Light Tactical Vehicle Branch were consulted for their concurrence with the selection of this profile/speed scenario. These scenarios were executed on the simulator during this consultation, and agreement was reached on all simulations.

7.3 Test Execution

The M101A2 trailer was subject to 3,000 miles of simulated road profile as detailed in Table 3.

Table 3 Test Mileage Breakout

Course	Miles with Payload	Miles no Payload	Speed
Gravel			
- Churchville 6	570	20	25 mph
- Churchville 7	570	20	25 mph
Level Cross-Country			
- APG 37	540	0	18 mph
- Letourneau 5_50	540	0	12 mph
Hilly Cross-Country			
- Letourneau 4_50	690	0	15 mph
Belgian Block			
- Churchville 7	20	30	25 mph
	-----	-----	
	2,930	70	

Testing commenced Feb 11, 1991, and concluded on Mar 1, 1991. The test was performed in the order of Table 3. For example, all 570 miles of Churchville 6 (with payload) were run before any other course was simulated.

On February 19, after 1,620 miles were completed, it was noticed that the trailer's left-side leaf spring was sagging slightly. The 1,500 pound payload was subsequently checked and recentered. At that time, measurements to determine the clearance between the jounce stop and frame were taken and are as follows:

Right side: 4.50 inch
Left side: 3.81 inch

The measurements were taken with a 1,500 pound dummy load symmetrically centered in the longitudinal and lateral axis above the axle. These measurements remained the same during the rest of the test. The payload required only a slight repositioning and did not affect the leaf spring sag. Both springs eventually held up properly throughout the test.

Simulator performance was monitored throughout the test. This ensured that the motion simulator produced the dynamics intended for each profile simulated.

7.4 Data Acquisition

The motion simulator and M101A2 trailer were instrumented with a variety of transducers. The data collected provide the engineering community with position, velocity and acceleration information to evaluate test results. It is also used to provide the design and test engineer with the required parameters needed to diagnose simulator or vehicle failures, if they occur. The data collected are summarized in Table 4. The data were recorded digitally using the CAMAC system and were low-pass filtered at 50 hertz and recorded at 100 samples per second. The data are retained in the System Simulation and Technology Division computer archives.

The specific transducers and amplifiers used in the data collection effort are detailed in Table 5.

Table 4 Data Recorded

M101 Data Acquisition 1/31/91

Accelerometers	Range	Scale Factor	Bandwidth	Filter
1. Left spindle vertical	+- 10 g	+0.5 vdc/g	dc - 100 hz	50 hz Sicos
2. Right spindle vertical	+- 10 g	+0.5 vdc/g	dc - 100 hz	50 hz Sicos
3. Hitch for/aft	+- 10 g	+0.5 vdc/g	dc - 100 hz	50 hz Sicos
4. Rear frame vertical	+- 10 g	+0.5 vdc/g	dc - 100 hz	50 hz Sicos
Gyros				
5. Pitch underneath on	+- 60 d/s	+39.8 mv/d/s	dc - 25 hz	50 hz Sicos
6. Roll body	+- 60 d/s	+7.0 mv/d/s	dc - 25 hz	50 hz Sicos
Commands				
7. Left CAMAC #1 dac	+- 6 inch	-1.0 vdc/inch	dc - 50 hz	50 hz Sicos
8. Right CAMAC #2 dac	+- 6 inch	-1.0 vdc/inch	dc - 50 hz	50 hz Sicos
LVDT's				
9. Left Act #1	+- 6 inch	-1.0 vdc/inch	dc - 50 hz	50 hz Sicos
10. Right Act #2	+- 6 inch	-1.0 vdc/inch	dc - 50 hz	50 hz Sicos

Table 5 M101A2 Instrumentation Documentation

Transducer	Model #	Serial #
Left channel		
accelerometer	Setra 141B	153768
actuator	K 230-555	262
accel amplifier	Meas. grp 2310	channel # 3
Right channel		
accelerometer	Setra 141B	153769
actuator	K 230-555	261
accel amplifier	Meas. grp 2310	channel # 2
Rate gyro	Humphrey RT02-002-01-1	111
Hitch for/aft accel	Setra 141B	153771
Hitch accel amplifier	Meas. grp 2310	channel # 4
Frame vertical accel	Setra 141B	153767
Frame accel amplifier	Meas. grp 2310	channel # 1

Analysis of the data quantifies the dynamic performance of the motion simulator and trailer. Statistics have been calculated on the data recorded for each of the 1,500 pound payload simulations. They are presented in the Data Analysis section of this report.

7.5 Data Analysis

Table 6 Data analysis - M101A2 trailer

Course description: Churchville 6, Secondary rd, 25 mph

Signal Name	rms	minimum	maximum
Rt. spindle accel(vert.)	1.27 g	-6.6 g	7.1 g
Lt. spindle accel(vert.)	1.22 g	-6.8 g	6.35 g
Hitch accel(for/aft)	0.117 g	-0.6 g	0.729 g
Rear frame center accel(vert)	0.247 g	-0.98 g	1.24 g
Angular rate(pitch)	2.05 d/s	-7.83 d/s	10.5 d/s
Angular rate(roll)	negligible - no roll in course		
Rt. position act cmd.	0.237 in	-0.793 in	0.795 in
Lt. position act cmd.	0.248 in	-0.825 in	0.822 in
Rt position act response	0.242 in	-0.717 in	0.802 in
Lt. position act response	0.246 in	-0.716 in	0.842 in

Table 7 Data analysis - M101A2 trailer

Course description: Churchville 7, Secondary rd., 25 mph

Signal Name	**rms**	**minimum**	**maximum**
Rt. spindle accel(vert.)	1.17 g	-3.77 g	4.08 g
Lt. spindle accel(vert.)	1.13 g	-3.57 g	4.03 g
Hitch accel(for/aft)	.109 g	-.325 g	.447 g
Rear frame center accel(vert)	0.228 g	-0.654 g	0.782 g
Angular rate(pitch)	1.82 d/s	-4.68 d/s	6.00 d/s
Angular rate(roll)	negligible - no roll in course		
Rt. position act cmd.	0.186 in	-0.472 in	0.579 in
Lt. position act cmd.	0.194 in	-0.491 in	0.603 in
Rt position act response	0.192 in	-0.494 in	0.591 in
Lt. position act response	0.194 in	-0.501 in	0.593 in

Table 8 Data analysis - M101A2 trailer

Course description: APG 37, Cross-country, 18 mph

Signal Name	rms	minimum	maximum
Rt. spindle accel(vert.)	1.00 g	-3.75 g	3.29 g
Lt. spindle accel(vert.)	0.99 g	-3.89 g	3.33 g
Hitch accel(for/aft)	0.104 g	-0.364 g	0.389 g
Rear frame center accel(vert)	0.357 g	-1.19 g	1.23 g
Angular rate(pitch)	4.15 d/s	-13.9 d/s	11.5 d/s
Angular rate(roll)	negligible - no roll in course		
Rt. position act cmd.	0.833 in	-2.44 in	1.72 in
Lt. position act cmd.	0.866 in	-2.54 in	1.79 in
Rt position act response	0.853 in	-2.48 in	1.78 in
Lt. position act response	0.872 in	-2.55 in	1.80 in

Table 9 Data analysis - M101A2 trailer

Course description: Letourneau 4_50, Cross-country, 15 mph

Signal Name	rms	minimum	maximum
Rt. spindle accel(vert.)	0.645 g	3.02 g	-3.26 g
Lt. spindle accel(vert.)	0.565 g	-2.67 g	2.86 g
Hitch accel(for/aft)	0.059 g	-0.482 g	0.378 g
Rear frame center accel(vert)	0.323 g	-1.08 g	1.41 g
Angular rate(pitch)	4.38 d/s	-17.1 d/s	17.0 d/s
Angular rate(roll)	5.04 d/s	-20.1 d/s	20.4 d/s
Rt. position act cmd.	0.682 in	-1.92 in	1.38 in
Lt. position act cmd.	0.625 in	-1.76 in	1.33 in
Rt position act response	0.698 in	-1.98 in	1.41 in
Lt. position act response	0.630 in	-1.78 in	1.34 in

Table 10 Data analysis - M101A2 trailer

Course description: Letourneau 5_50, Cross-Country, 12 mph

Signal Name	rms	minimum	maximum
Rt. spindle accel(vert.)	0.572 g	-4.36 g	5.67 g
Lt. spindle accel(vert.)	0.599 g	- 4.01 g	4.66 g
Hitch accel(for/aft)	.062 g	-0.599 g	0.99 g
Rear frame center accel(vert)	0.32 g	-1.32 g	1.31 g
Angular rate(pitch)	4.55 d/s	- 15.8 d/s	16.1 d/s
Angular rate(roll)	5.50 d/s	-18.7 d/s	16.2 d/s
Rt. position act cmd.	0.969 in	-2.09 in	2.43 in
Lt. position act cmd.	1.07 in	-2.97 in	2.44 in
Rt position act response	0.992 in	-2.15 in	2.50 in
Lt. position act response	1.08 in	-3.05 in	2.45 in

Appendix

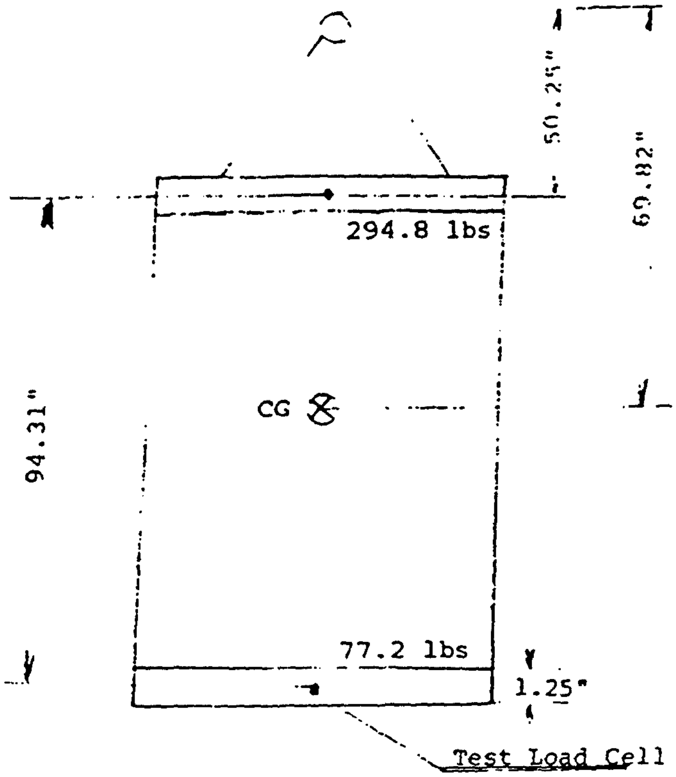
Comparison Weights and Center of Gravities of the M101A2 and Turtle Mountain M101A3 Trailers

TURTLE MOUNTAIN M101 TRAILER WEIGHT TABLE

Turtle Mountain Axle Assembly without Tires	242 lbs
Shock Absorber	3 1/4 lbs each
Leaf Spring (6 leaves)	41 3/4 lbs each
Chassis (M116)	372 lbs
Cargo Box (Turtle Mountain M101A3)	846.4 lbs
Cargo Box (KASEL M101A2)	448 lbs
Radial HMMWV Tire 37X12.5XR16.5 with Rim	127 lbs

CHARACTERIZATION OF THE TURTLE MOUNTAIN
TRAILER WITH M116 FRAME AND 6 LEAf
SPRING CONFIGURATION

HORIZONTAL CENTER OF GRAVITY OF THE M116 CHASSIS



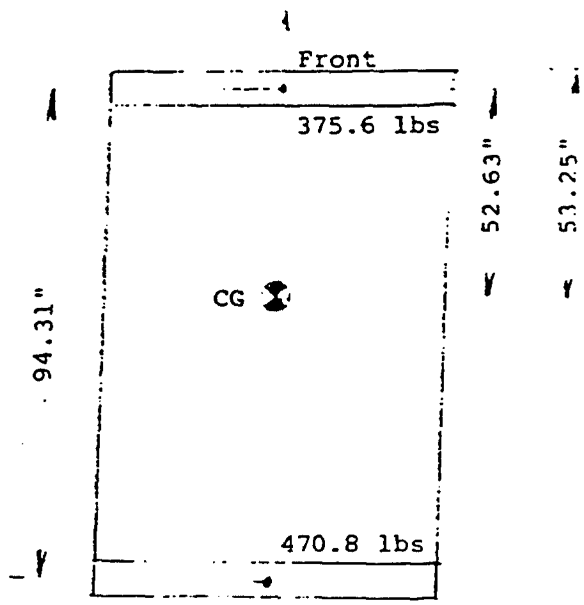
TOTAL WEIGHT = 372.0 lbs

$X_1 = \frac{77.2 \times 94.312}{372} = 19.57"$

$X_2 = \frac{294.8 \times 94.312}{372} = 74.74"$

Horizontal center of gravity of the M116 Chassis is 69.82" away from the end of the lunette.

HORIZONTAL CENTER OF GRAVITY OF THE
TURTLE MOUNTAIN MODIFIED M101A3 BOX



Test Load Cell

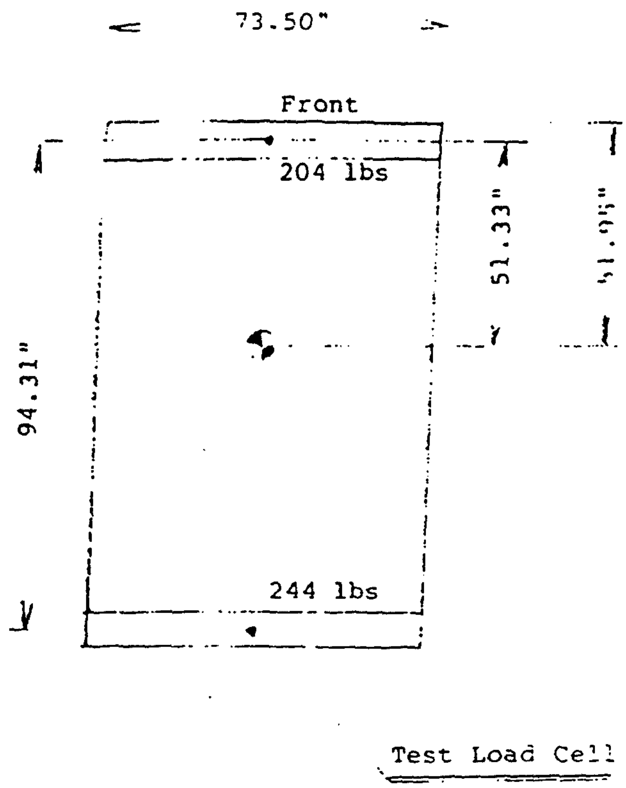
TOTAL WEIGHT = 846.4 lbs

$$X_1 = \frac{470.8 \times 94.625}{846.4} = 52.63"$$

$$X_2 = \frac{375.6 \times 94.625}{846.4} = 49.99$$

Center of gravity is 53.255" away from the front of the box.

HORIZONTAL CENTER OF GRAVITY OF THE KASEL BOX (M101A2)



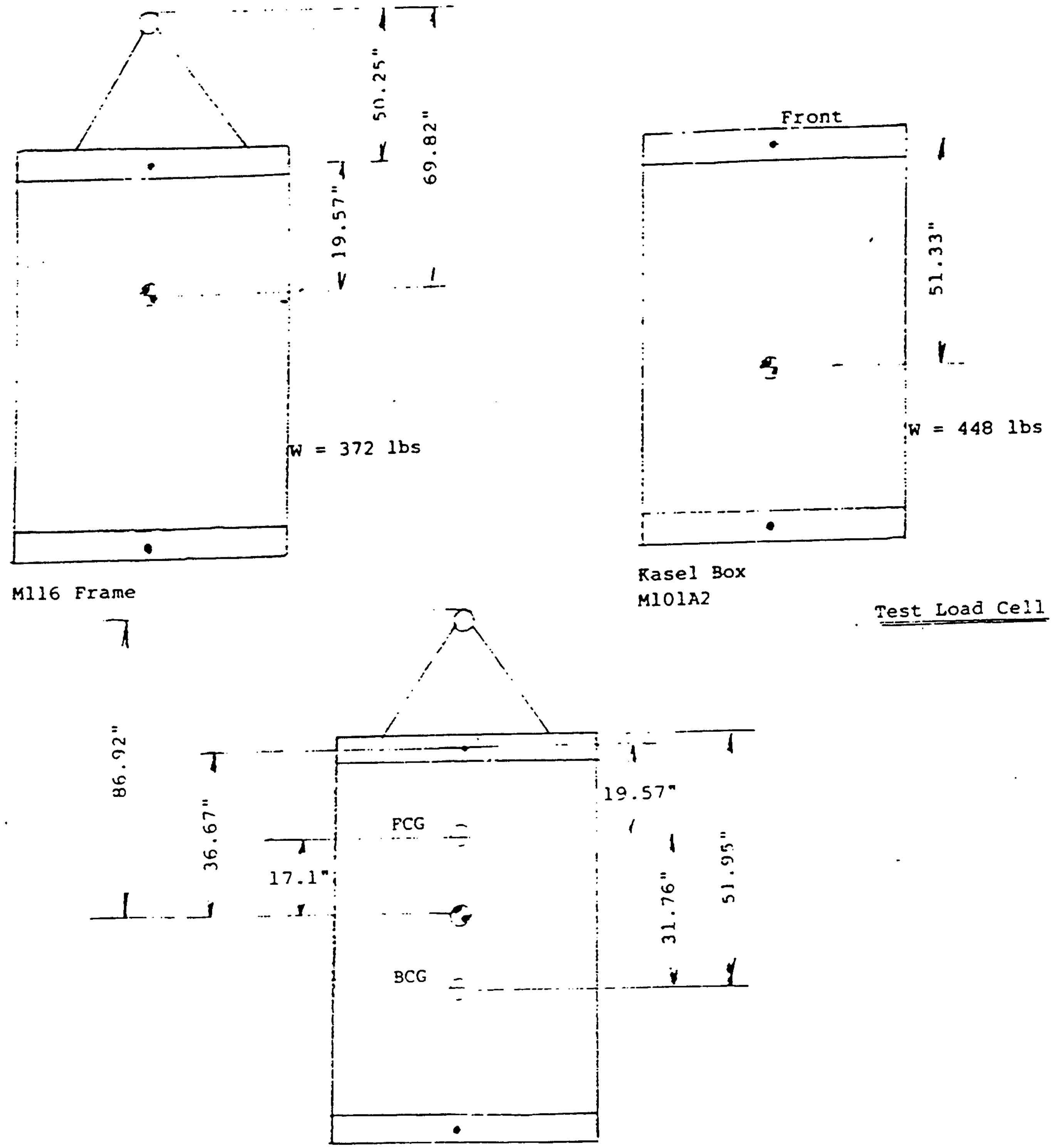
TOTAL WEIGHT = 448 lbs

$$X_1 = \frac{244 \times 94.625}{448} = 51.33"$$

$$X_2 = \frac{204 \times 94.625}{448} = 43.08"$$

The Center of gravity is 51.95" away from the front of the box.

RESULTANT CENTER OF GRAVITY OF THE M116 FRAME AND KASEL BOX (M101A2) (Analytical Determination)

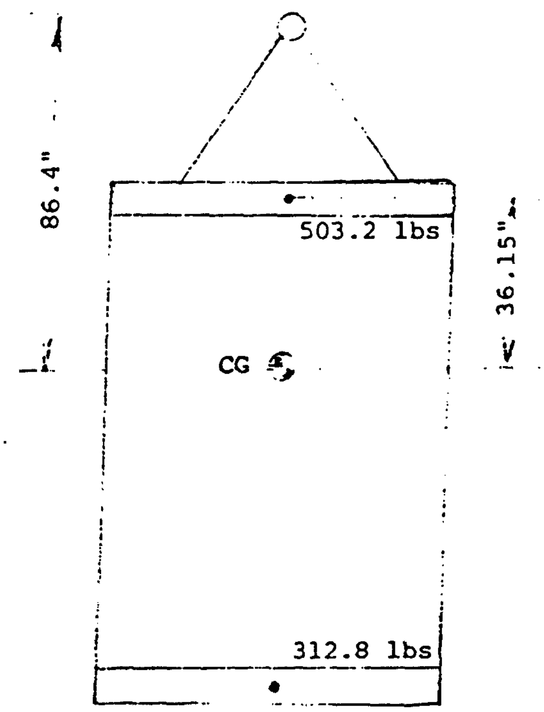


$W = 372 + 448 = 820$ lbs

$X_1 = \frac{448 \times 31.76}{820} = 17.1"$

Resultant center of gravity is 86.92" away from the lunette's end.

RESULTANT CENTER OF GRAVITY OF THE M116 FRAME (CHASSIS)
AND KASEL BOX (M101A2) TEST DETERMINATION

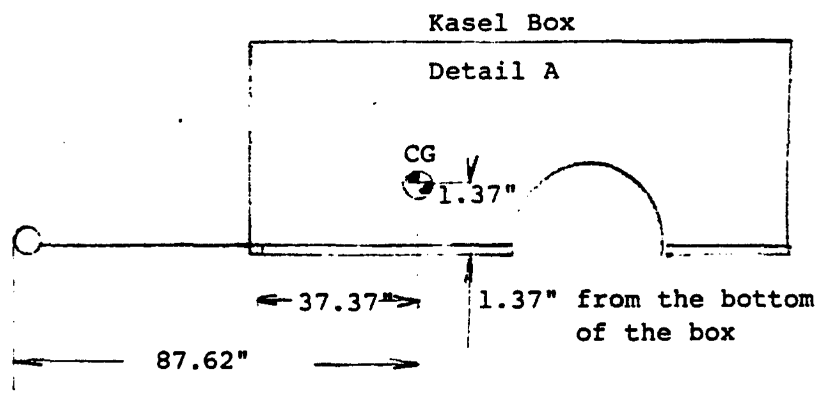


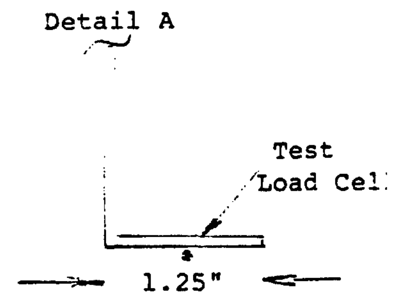
$$W = 312.8 + 503.2 = 816 \text{ lbs}$$

$$X_1 = \frac{312.8 \times 94.31}{816} = 36.15"$$

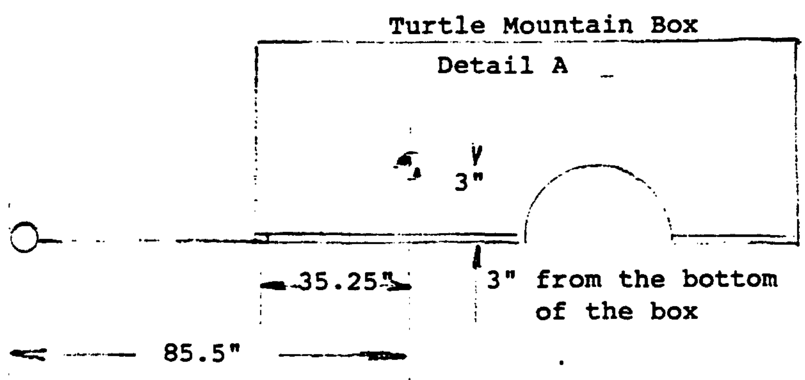
NOTE: From the analytical determination, the combined Center of gravity was found to be 36.67" away from the point where the front test load cell was placed. This physical test revealed that the Center of Gravity is 36.15" from the front test load cell or 86.4" from the end of the lunette.

VERTICAL CENTER OF GRAVITY
KASEL BOX (M101A2) AND M116 CHASSIS





VERTICAL CENTER OF GRAVITY
MODIFIED TURTLE MOUNTAIN BOX M101A3 AND M116 CHASSIS



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