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SOLDIER-MACHINE PERFORMANCE FIELD TRIALS - AMMUNITION LOADING OF THE PALLETIZED LOADING SYSTEM

John D. Waugh

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U.S. ARMY HUMAN ENGINEERING LABORATORY
Aberdeen Proving Ground, Maryland

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The Combat Service Support Division of the U.S. Army Human Engineering Laboratory conducted a series of field trials uploading ammunition onto a surrogate of the Army's latest generation of tactical transport, the Palletized Loading System (PLS), a 15-ton payload capacity truck equipped with a demountable flatrack instead of a conventional fixed bed. Twelve recent graduates from the advanced individual training course for ammunition handlers (military occupational speciality 55B) were tasked to load and secure PLS flatracks, both grounded and on board PLS trucks, with pallets of ammunition. Two types of typical high usage ammunition were chosen, 155mm artillery projectiles and 105mm tank cartridges for armored units. Each of the ammunition types was further subdivided as uniform loads where the flatracks are loaded with identical pallets of one commodity and Unit Configured Loads (UCLs), a mix of projectiles and propellant charges for the artillery loads, and a mix of 105mm cartridges and small arms ammunition for the armor loads.

The experimental results and subsequent comparative statistical analysis showed that (a) loading and securing grounded flatracks was faster than loading on board trucks and (b) armor ammunition loads took less time than artillery ammunition loads. There were no differences in the total times foı UCL versus uniform loads; however, the time to secure an artillery UCL was greater than for the uniform load, probably because a more difficult tie-down routine with more tie-down straps was being used. (See reverse side.)

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19. It was concluded that the mean times for uploading are representative and that the preparation of grounded flatrack loads, prior to the arrival of convoyed PLS assets, would probably enhance the issuing operations of corps storage areas and ammunition supply points.

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SOLDIER-MACHINE PERFORMANCE FIELD TRIALS - AMMUNITION LOADING OF THE PALLETIZED LOADING SYSTEM

INTRODUCTION

The dates of the field trials were 29 October - 17 November, 1987.

The U.S. Army is acquiring a transportation system known as the Palletized Loading System (PLS), primarily for the supply and resupply of ammunition in a theater of war. The Army's first encounter with the system was in September, 1983, at the "Caber Toss" field exercise at the Yakima Firing Center, Washington, where an original British version of the system was demonstrated.

This vehicle is equipped with a cargo "flatrack" in lieu of a fixed truck bed. The truck bed can be lowered to the ground behind the vehicle by the driver in the cab utilizing a unique hydraulic system. The vehicle is also equipped with a four-wheel trailer that carries an identical flatrack. Flatracks can be transferred from the trailer to the PLS truck and from the PLS truck to the trailer. Figure 1 illustrates one of the PACCAR-Kenworth® PLS surrogate vehicles (called such because the acquisition process for the Army version had not yet begun) leased to the Army for the Force Development Test and Experimentation (FDTE) which took place at Fort Hood, Texas, in October and November of 1986 (U.S. Army Training and Doctrine Command, Combined Arms Test Activity [TCATA], 1987). Two of these surrogates were subsequently acquired and brought to the U.S. Army Human Engineering Laboratory (HEL).

The ingenious configuration and added capabilities of the PLS vehicle allow the pre-loading and securing of PLS flatracks with ammunition at the corps storage area (CSA) and/or the ammunition supply point (ASP). This capability was thought to potentially provide a significant reduction in the time required for the issue of ammunition.

As with any new concept, PLS has generated a myriad of questions and issues, not the least of which is whether it can be effectively employed in any Army system of resupply for ammunition and whether the Army will realize an increase in productivity, or conversely, a savings in manpower, and/or equipment. As a part of these large scale issues, HEL has the responsibility for examining the soldier-vehicle performance aspects of the concept and for extending the technical data base to cover field operations where PLS would be in use. The test report of the above-mentioned FDTE did not report the amount of time it took to upload and secure the various ammunition loads onto PLS trucks (TCATA, 1987). The data in this report will fill this gap and should be useful to both materiel developers (U.S. Army Materiel Command [AMC]) and the proponents for ammunition handling, transportation, and resupply (U.S. Army Training and Doctrine Command [TRADOC]).

This report describes field trials recording human performance employing alternative methods of loading and servicing various types of ammunition on PLS toward finding a better way of supplying ammunition to the users.

Figure 1. PACCAR-Kenworth Palletized Loading System surrogate truck.

Currently, to upload issued ammunition, the using unit's trucks must spend a significant amount of time in the vicinity of the field storage unit (FSU). Given that the CSA does not possess an inexhaustible number of forklifts and operators, the more trucks the unit sends back for ammunition, the longer it will take to upload them. Even if the particular types and amounts of ammunition designated for that unit are known and set aside ahead of time, it will still take on the order of 20 plus minutes to load each truck (Shearin, Kupets, & Gillis, 1985). On the other hand, if the types and amounts of ammunition are known ahead of the unit's trucks' arrival and are set out on PLS flatracks, the unit transport will spend a significantly shorter amount of time in the FSUs. It would take about the same amount of time and assets to load and secure ammunition on the flatracks as it would on conventional trucks, but the PLS truck's total time in the CSA or ASP might be reduced. In situations where time did not permit the advance preparation of loaded flatracks, the PLS truck could still be uploaded and secured like any other truck.

OBJECTIVE

The objective of these field trials was to gather soldier-machine performance data associated with PLS as an ammunition transporter. Several types and configurations of ammunition were examined in field trials for loading and securing flatrack loads on the truck and on the ground. Statistical analysis techniques examined differences in these variations.

The primary purpose is to expand the human factors engineering (HFE) data base and seek enhancements in handling and issuing ammunition on the battlefield.

METHODOLOGY

Test Participants

The test participants (TPs) consisted of 12 active duty soldiers, just graduated from the military occupational speciality (MOS) 55B (Ammunition Specialist) advanced individual training (AIT) course at the U.S. Army Ordnance Missile and Munition Center and School (OMMCS). The personnel employed were selected by TRADOC. Those personnel selected to operate PLS vehicles and 6,000-lb Rough Terrain Forklifts (RTFLs) were locally trained and refreshed on these vehicles prior to the start of the timed trials. MOS 55B AIT personnel received training on the RTFLs as part of their training curriculum. Limited additional training was provided by HEL for operation of PLS trucks. Operation of these vehicles was limited to the test site at the HELFAST Test Site at the Edgewood Area of Aberdeen Proving Ground.

The makeup of the TPs was ten male and two female soldiers; rank ranged from Private, E1, through Private First Class, E3, and ages ranged from 20 through 25 years.

Apparatus

Equipment

Two PLS "surrogate" vehicles with flatracks (15-ton payload capacity)

Two 6,000-lb capacity RTFLs, MHE 222

One 16,000-lb capacity RTFL, Gradall®, commercial, used to reposition ammunition only - not used in timed trials

Palletized inert and dummy ammunition: M107 155mm projectiles, M3, M4, and M119 155mm propellant containers, PA104 tank ammunition containers, and mixed boxed small arms ammunition. All ammunition pallets were loaded to specified weights (Department of the Army, 1981)

Ammunition tie-down straps--NATO standard, nylon, with ratchet.

Stopwatches (1-second scale divisions)

Safety Features of the Equipment

All equipment used with the exception of PLS vehicles and PLS trailers were standard issue items that are normally safety certified when placed in the federal inventory. The PLS vehicles had previously been safety certified by the Army prior to similar testing with military operators as part of the PLS vehicle and trailer trials conducted at Fort Hood, Texas. No special safety requirements existed other than the normal safety procedures followed for operation of the equipment specified above.

Field Trials Site Layout

Figure 2 is a schematic of an ammunition field storage unit (FSU) for a typical test setup. This layout is in accordance with quantity-distance (Q-D) standards of Federal Manual 9-13 and Technical Manual 9-1300-206.

Procedure

Briefing Procedures

All TPs and other participating personnel were thoroughly briefed regarding the trial's objectives, human use issues including informed consent and withdrawal from the trials, risks, and safety checks and procedures prior to the start of training. Everyone participated in a terrain walk through the test site and was given a verbal description of the materiel and equipment to be used in the field trials. They were again briefed immediately prior to the beginning of each sub-test set of trials to assure that all the TPs thoroughly understood what was to be accomplished.

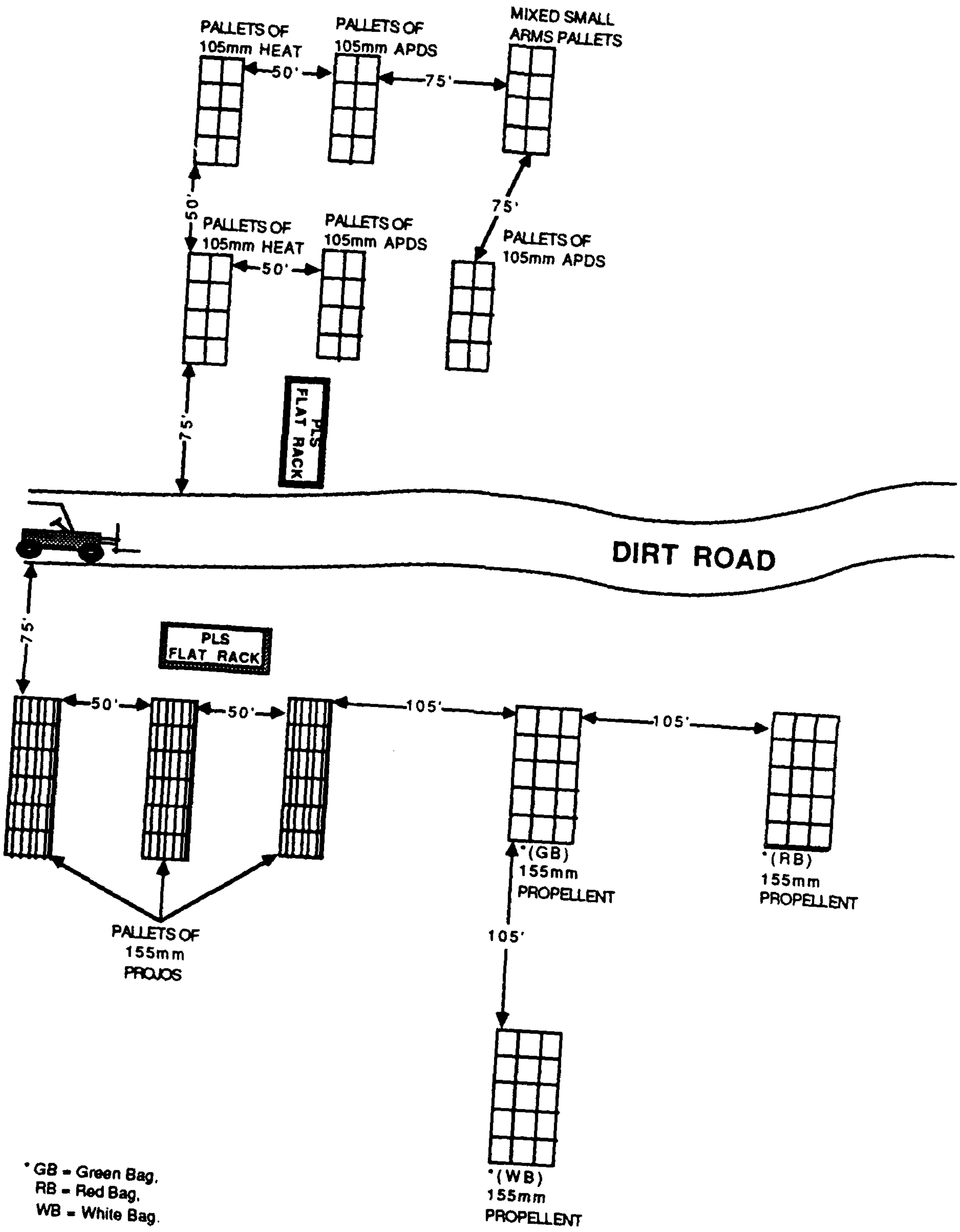

Figure 2. Schematic of field storage unit layout.

Training and Training Assessment

Each of the 12 TPs was given an opportunity to work with the RTFLs in practice loading trials. The four most proficient TPs, in the joint opinion of the investigators, were designated as RTFL operators during the field trials. A similar natural selection of operators takes place in the real world of ammunition handling. These four TPs were assigned to the other team positions during trials when they were not operating the RTFLs. Each TP was given additional training on the PLS trucks until an errorless level of performance was accomplished. The use of ammunition tie-down straps and the ground guiding of RTFLs were demonstrated to each individual. Each TP then performed the required operations until the individual possessed the required proficiency, based on smoothness of operation and lack of errors. One complete iteration of the field trials was conducted for learning prior to conducting trials for record. Successive trial times were within 10% by the end of this iteration.

Conduct of the Field Trials

The PLS flatracks (on the truck or on the ground), as illustrated above, were located approximately central to the stacks, but adjacent to the roadway, within the FSUs. The starting positions of the RTFLs were near the roadway and the corner of the FSUs. The assigned team of six soldiers (see the experimental design section) were instructed to load and secure a flatrack load of the specified ammunition. The flatrack to be loaded may have been on the truck or on the ground. Upon receiving the start signal, the RTFL moved into the appropriate ammunition stack, picked up the first pallet, and deposited it on the flatrack (for artillery projectiles, normal practice is for the RTFL to lift three pallets strapped together at a time). This operation was repeated until the flatrack was filled with the prescribed amount of ammunition. There were ground guides for the RTFL operator located in the stacks and at or on the flatrack. When a sufficient number of pallets had been positioned on the flatrack, the two load-securing members of the team began to place and draw tight their tie-down straps in the appropriate pattern for that load according to illustrations provided in a pamphlet[1] by the U.S. Army Defense Ammunition Center and School (USADACS). Note that the securing of the load could begin before the entire load was placed on the flatrack, but only when sufficient pallets had been already loaded, however, to ensure that the soldiers securing the load were well removed from the forklift operation. If the timed trial involved loading the flatrack while on the truck, the trial ended when the last tie-down strap was secured. If the flatrack was loaded while grounded, the PLS driver was instructed to back the truck (approximately 30 feet), acquire and lift the flatrack onto the truck. At this point, the trial ends.

Upon completion of each trial, the loaded ammunition was unsecured, the tie-down straps were collected and made ready for the next trial, and the ammunition pallets were removed from the flatrack and placed back in the appropriate stacks. This was done by the same team that had just completed the trial. A 2-hour block of time (four trials in 8 hours) was initially planned for each complete trial, to include repositioning of the ammunition. In actual fact, the TPs logged seven to eight trials in an 8-hour day.

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[1] USADACS pamphlet Securing PLS Ammunition Loads (not known to be published, but distributed at the exercise).

Upon completion of the main body of field trials, a single complete iteration of trials was conducted in which already loaded flatracks were secured, to compare against the securing of the loads while the forklift operation was still in progress.

The test site contained two FSUs, one with 155mm high explosive (HE) artillery projectiles and propellant charges and the other with 105mm tank main gun ammunition and mixed small arms pallets typical of an armor unit's requirements. Trials were conducted in each FSU simultaneously; the odd-numbered teams occupying one FSU and the even-numbered teams occupied the other. Two data-collection teams of two members each were employed, one team for each FSU.

Data Collection

Data collection includes the following times for each sub-test:

Time "start loading"--recorded when the team is given the signal to start loading pallets on the PLS flatrack and RTFL moves to the appropriate stack for the first pallet

Time "stop loading"--recorded when the RTFL tines clear the last pallet of the load

Time "start securing the load"--recorded when the TPs began to secure the load with tie-down straps

Time "load secured"--recorded when the last tie-down strap has been placed over the load and properly tightened. This ended the trial for flatracks loaded up on the truck bed.

Time "load on the truck"--recorded when the loaded flatrack was lifted onto the truck bed, ending the trial

Times were recorded to the nearest second using the stopwatches and transferred to the master data sheets to the nearest decimal fraction of a minute in order to simplify the subsequent analysis. TPs mistakes and errors were recorded as comments on the data-collection sheets.

EXPERIMENTAL DESIGN

Description of Independent, Dependent, and Control Variables

Dimensions and Independent Variables

The experiment is arranged as a complete three-dimensional repeated measures design (two factors x subjects) (Lindquist, 1956).

Type of Ammunition

155mm HE artillery projectiles, eight projectiles per pallet, three palle_s per RTFL lift

155mm artillery Unit Configured Load (UCL)[2] HE projectiles and propellant charges

105mm tank cartridges in steel containers, 30 rounds per pallet

105mm tank UCL, mix of high explosive antitank (HEAT) and armor-piercing fin-stablized discarding sabot (APFSDS) round pallets, plus one pallet mixed small arms

PLS Flatrack Posture

Flatrack placed on the ground for loading

Flatrack placed on the truck bed for loading

TPs (Teams)

Eight teams[3]

Replications

Two complete sets of trials for each team

Dependent Variables and Controls

The criterion measures were

Time for the RTFL to complete the loading of each flatrack with ammunition

Time to secure the load on each flatrack

Total time to load and secure each flatrack

---

[2] A UCL, as defined by the HEL Combat Service Support Division (Shearin, Kupets, & Gillis, 1985), is a single truckload of ammunition, containing a mix of palletized ammunition types, as required by the battle scenario, so that the truck transporting the UCL may deliver the entire load to a single unit. This is opposed to a truckload of a single type of ammunition or uniform load, for example, HE artillery projectiles, that must seek and deliver a portion of its load to three different batteries, for example, and a second and even a third truck must go through the same routine with propellant charges.

[3] Twelve TPs, two groups of six TPs each, assigned to four teams for each group, in a balanced order of team assignments, including two permanent RTFL operators per group, for an aggregate of eight teams performing in each cell of the experimental design.

Time to lift each grounded, loaded flatrack onto the PLS truck bed (one half of the total number of trials)

Time to secure a flatrack load where the entire load of ammunition is placed on the flatrack prior to beginning the securing procedure--separate set of trials, one complete iteration (one half of the total number of trials).

Errors were recorded in the comment section of the data-collection sheet.

Order of Presentation and Team Assignments

Tables 1 and 2 are matrices of the experimental design showing the order of presentation (trial numbers) for the first and second replications, respectively.

Team Assignments

Each of the TPs was assigned a TP number from 1 through 12 (TPs 1 through 4 were designated RTFL drivers), randomly. The 12 TPs were repeatedly divided into teams of 6 TPs each. All the odd-numbered TPs were assigned to odd-numbered teams and worked together throughout the trials, rotating through the various teams assigned positions in a balanced order of presentation. The same followed for the even-numbered TPs, that is, TP numbers 2, 4, 6, 8, 10, and 12 were assigned positions on team numbers 2, 4, 6, 8. Eight teams were formed. Table 3 is the team assignments.

The layout of the ammunition FSU, the distances the RTFL travels from the FSU stacks of ammunition to the flatrack, the orientation and configuration of ammunition in FSUs, as loaded on the flatracks, and securing configurations are all held constant. The same RTFLs and PLS trucks were assigned to their respective FSUs for the duration of the field trials.

Because of the limited quantity of inert or dummy ammunition available and because of the limited number of PLS test vehicles and flatracks, the ammunition used in each sub-trial was recovered upon completion of the sub-trial and returned to the ammunition storage stacks prior to start of the next trial. Recovery of ammunition was performed by TPs; however, this performance was not subject to timed trials or data collection. Occasionally, pallets of ammunition were damaged or broken in handling. When this occurred, the pallet was removed from the FSU and set aside for repair. Sufficient dummy ammunition was available to replenish the stacks. Periodically, the TPs and staff interrupted the trials to accomplish the repairs and place the pallets back in service.

DATA ANALYSIS AND RESULTS

Data analysis was performed on a VAX® 11/780 computer using the SAS® software.

Independent variables for this field study were type of ammunition (artillery UCL, artillery uniform load, armor UCL, Armor uniform load, and PLS

Table 1

Design Matrix Showing Order of Presentation (Trial Number) for the First Replication

Type of ammunition	155mm		105mm		Artillery UCL		Armor UCL	
Sub-test	A	B	C	D	E	F	G	H
Flatrack	Gnd[a]	Veh	Gnd	Veh	Gnd	Veh	Gnd	Veh
Team No. (six TPs each)								
1	1	48	11	54	21	60	31	34
2	47	2	53	12	59	22	33	32
3	25	56	3	62	13	36	23	42
4	55	26	61	4	35	14	41	24
5	17	64	27	38	5	44	15	50
6	63	18	37	28	43	6	49	16
7	9	40	19	46	29	52	7	58
8	39	10	45	20	51	30	57	8

[a] - Ground

Table 2

Design Matrix Showing Order of Presentation (Trial Number) for the Second Replication

Type of ammunition	155mm		105mm		Artillery UCL		Armor UCL	
Sub-test	A	B	C	D	E	F	G	H
Flatrack	Gnd[a]	Veh	Gnd	Veh	Gnd	Veh	Gnd	Veh
Team No. (six TPs each)								
1	85	108	95	98	65	128	75	118
2	107	86	97	96	127	66	117	76
3	77	100	87	122	89	120	67	110
4	99	78	121	88	119	90	109	68
5	69	124	79	114	81	112	91	102
6	123	70	113	80	111	82	101	92
7	93	116	71	106	73	104	83	126
8	115	94	105	72	103	74	125	84

[a] - Ground

Table 3

Assignment of Test Participants to Teams

	Driver	PLS guide	Tie-Down 1 ratchet end	Tie-Down 2 plan end	FSU Guide (checker)	PLS driver
Team 1	1	5	7	9	3	11
Team 2	2	6	8	10	4	12
Team 3	3	7	9	11	1	5
Team 4	4	8	10	12	2	6
Team 5	1	9	11	5	7	3
Team 6	2	10	12	6	8	4
Team 7	3	11	5	7	9	1
Team 8	4	12	6	8	10	2

Note. RTFL drivers are always TPs 1 through 4.

posture [flatrack grounded, flatrack truck mounted]). Dependent variables were forklift loading time, time to secure the load, and total time. Separate lift times on grounded flatracks only and secure times only (these operations performed sequentially instead of concurrently) were recorded also. In the various analysis tables appearing in this section, "SECURE" or "SECURE 1" refers to the load securing times taken concurrently with the process of loading the flatracks (the bulk of the trials), and "SECURE 2" refers to those times where the tie-down procedure was performed separately. Table 4 shows the mean performance times for each condition of the trials.

A repeated measures multivariate analysis of variance (MANOVA) was performed on the dependent variables for time (load, secure, and total) in order to examine main effects differences between ammunition type, PLS posture, and interaction effects. Table 5 shows the main effects results.

The MANOVA performed indicates a significant main effect for both ammunition type and posture. There were no interaction effects.

Separate univariate analyses of variance (ANOVAs) were performed on the LOAD time for grounded flatracks,SECURE 1 time, and for SECURE 2 time. The ANOVA performed on GROUND lift times indicated no significant main effects. For the SECURE 1 case, the ANOVA indicated a significant main effect for both ammunition type and for PLS posture. For the SECURE 2 case, there was a significant main effect for only PLS posture. Tables 6 and 7 show the significant ANOVA values.

When significant differences in individual variables existed, Scheffé's post hoc comparison was performed between means. Table 8 summarizes these comparisons.

Table 4

Mean Performance Time (minutes)

	LOAD	SECURE 1	SECURE 2	TOTAL	TOTAL with lift
Artillery UCL					
Ground	25.43	10.15	8.64	30.91	33.12
Vehicle	29.74	12.97	7.96	35.17	
Artillery Uniform LOAD					
Ground	22.49	15.65	7.38	28.99	31.01
Vehicle	28.71	21.29	11.21	37.32	
Armor UCL					
Ground	18.30	10.60	7.82	22.30	24.43
Vehicle	25.22	15.43	7.80	32.10	
Armor Uniform LOAD					
Ground	18.75	13.18	6.28	24.48	26.63
Vehicle	20.59	14.36	10.41	28.33	

Table 5

MANOVA for LOAD, SECURE, TOTAL Times

Source of variation	df	F-ratio	Significance level
Ammunition	9,47	51.91	.01
Posture	3,5	32.11	.01

Table 6

ANOVA for SECURE 1 Times

Source of variation	df	F-ratio	Significance level
Ammunition	3,21	72.69	.01
Posture	1,7	10.76	.05

Table 7

ANOVA for SECURE 2 Times

Source of variation	df	F-ratio	Significance level
Posture	1,7	11.96	.01

Table 8

Comparisons of Mean Times, Significance Levels

	LOAD		SECURE		TOTAL	
Ground	22.49	.05	14.27	.05	26.67	.05
Vehicle	25.22		16.54		32.09	
Armor	19.87	.05	12.81	.05	25.80	.05
Artillery	26.60		15.02		33.12	
UCL	22.64	NS	16.12	.05	29.80	NS
Uniform LOAD	24.78		12.29		30.12	
Artillery UCL	27.59	NS	21.72	.05	33.18	NS
Artillery uniform load	25.60		14.55		33.03	
Armor UCL	20.07	NS	12.87	NS	26.69	NS
Armor uniform load	19.67		12.47		24.90	

The Scheffé comparisons indicate that the means for LOAD, SECURE, and TOTAL operational times were all significantly longer for on-vehicle loaded ammunition than for grounded flatracks, $F_{(1,7)}=5.92$, <.05. Contrast of the means for ammunition type in these field trials indicates that armor (both UCLs and uniform load configurations) LOAD, SECURE, and TOTAL operational times were significantly faster than for artillery, $F_{(1,21)}=3.07$, <.05. Within the armor and artillery comparisons, the UCL was not significantly faster than the uniform load, except for a faster uniform load secure time, $F_{(1,21)}=3.07$, $<.05$. Comparisons between artillery UCL and uniform loads, and armor UCL and uniform loads indicated that no significant differences existed except for a faster time to SECURE the artillery uniform load, $F_{(1,21)}=3.17$, $<.05$. A Scheffé test was also performed on mean times for SECURE 1, compared to SECURE 2, which indicated that securing grounded flatracks went significantly faster than up on the vehicle, $F_{(1,7)}=5.60$, $<.05$.

Finally, a series of three-way ANOVAs was performed on the LOAD, SECURE, and TOTAL times, the third dimension being Teams, shown in Tables 9, 10, and 11, respectively.

Table 9

Three-Way ANOVA for LOAD Times

Source of variation	df	F-ratio	Significance level
Ammunition	3	66.29	.01
Posture	1	66.55	.01
Team	7	12.12	.01
Ammo x Team	21	1.06	NS
Ammo x Posture	3	3.49	.05
Posture x Team	7	1.34	.05
Ammo x Posture x Team	21	.52	NS

Table 10

Three-Way ANOVA for SECURE Times

Source of variation	df	F-ratio	Significance level
Ammunition	3	83.98	.01
Posture	1	23.28	.01
Team	7	4.41	.01
Ammo x Team	21	.51	NS
Ammo x Posture	3	1.11	NS
Posture x Team	7	.88	NS
Ammo x Posture x Team	21	.65	NS

Table 11

Three-Way ANOVA for TOTAL Times

Source of variation	df	F-ratio	Significance level
Ammunition	3	47.73	.01
Posture	1	80.55	.01
Team	7	2.23	.05
Ammo x Team	21	.63	NS
Ammo x Posture	3	2.40	NS
Posture x Team	7	.63	NS
Ammo x Posture x Team	21	.46	NS

As expected, the ANOVAs produced significant F-ratios for the main effects of ammunition and posture; they also produced significant F-ratios for Teams for each of the times examined. It is of no interest to further analyze these results to determine if one or more teams was either significantly faster or slower at performing their tasks. The only interactions present, according to the analyses, occurred in the LOAD times for Ammo x Posture and Posture x Team.

DISCUSSION

Ammunition

The above analyses revealed a significant main effect attributable to ammunition type on time to load, time to secure, and the aggregate or total time spent (not including times for picking up the grounded flatracks). It definitely takes less time to make up an armor load than it does for a load of artillery ammunition. This was to be expected for armor loads because there were fewer lifts performed by the RTFLs and because the prescribed tie-down routine was simpler. The analysis showed, however, that there was not any real difference in the time it took to load a uniform versus UCL load of armor ammunition. The same was indicated for uniform versus UCL loads of artillery ammunition. For armor loads, the number of pallets to be placed on the flatrack was the same in each case, and the size of all the pallet bases were identical as well. Also, the times to secure the armor uniform and UCL loads were essentially the same because the tie-down routine did not change (see Figures 3 and 4). For artillery loads, times to load pallets onto the flatrack and the total (load and secure) times were statistically the same. However, the time taken to secure the pallets of the artillery UCL was statistically greater than for the uniform load, probably because the addition of propellant charge pallets to the flatrack made the securing portion of the job a bit more difficult with more tie-down straps to deploy (see Figures 5 and 6). This means that although it took longer to strap down the artillery UCL, it was not sufficient to make a difference in the aggregate load and secure times between uniform and UCL artillery loads.

Figure 3. Armor ammunition uniform load.

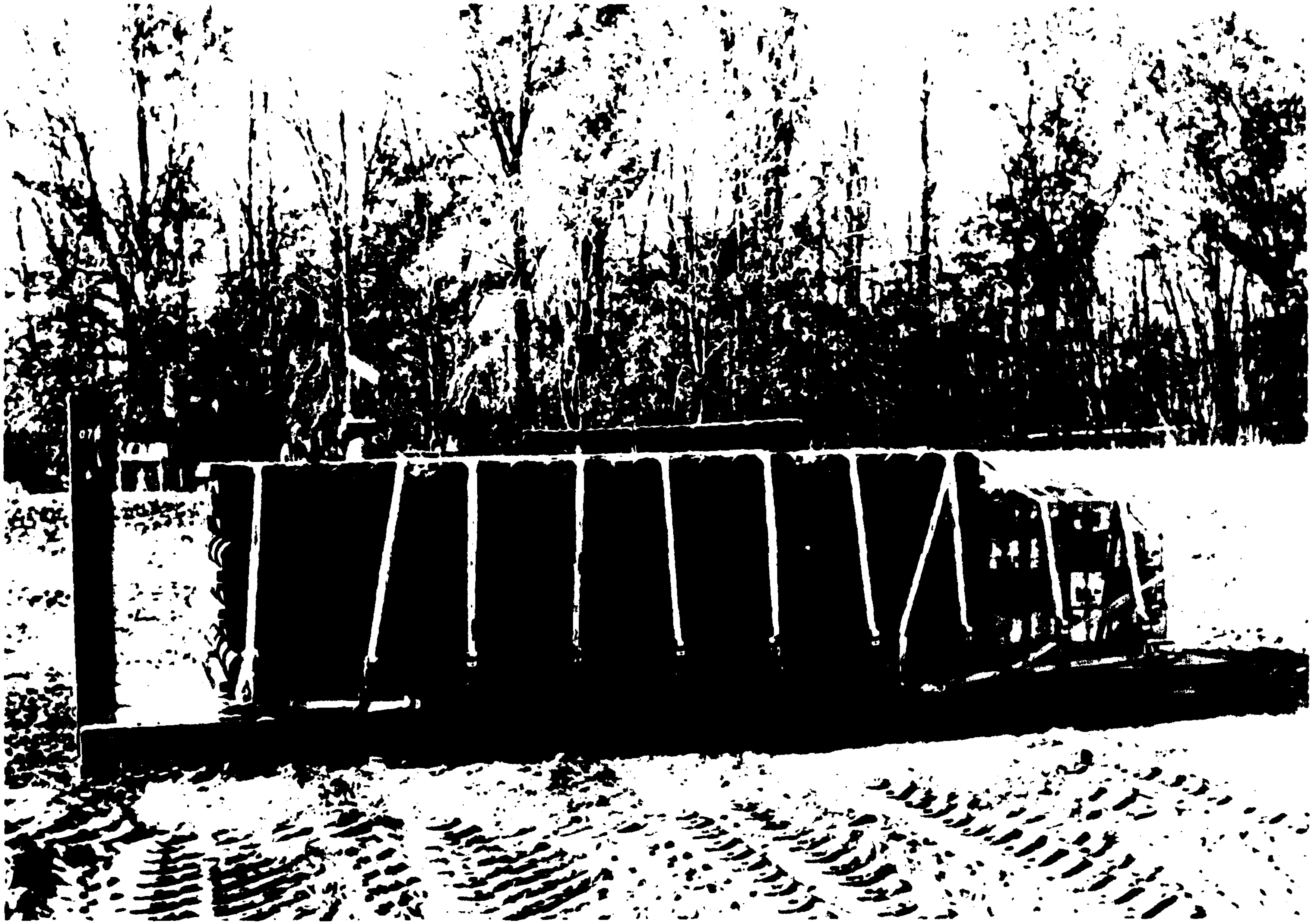

Figure 4. Armor ammunition Unit Configured Load.

Figure 5. Artillery ammunition uniform load.

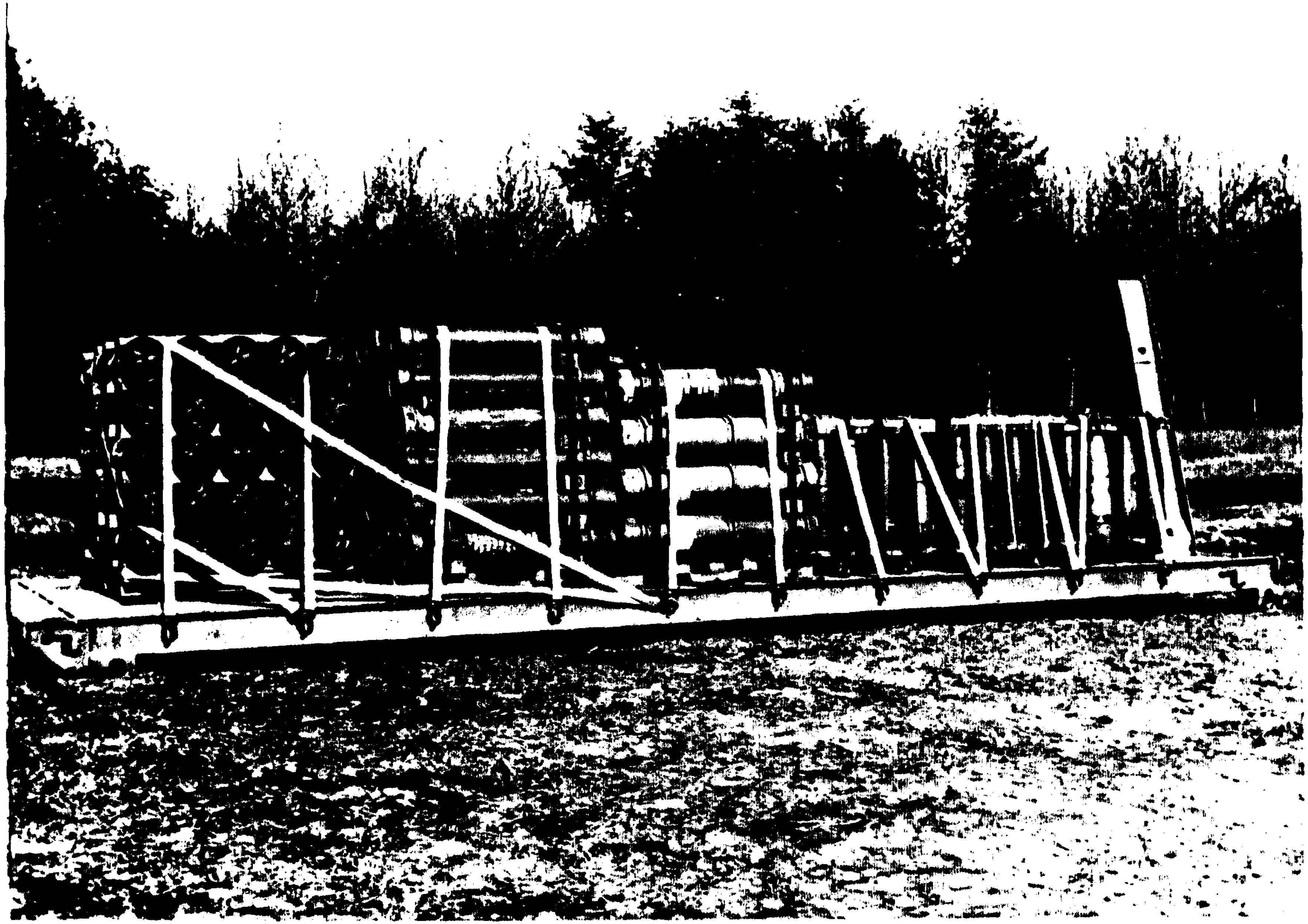

Figure 6. Artillery ammunition Unit Configured Load.

Posture

The analysis showed a significant main effect for the time to load a grounded flatrack versus loading the flatrack up on the vehicle, and additionally that this significant effect indicated that it positively took longer to load and to secure the loads, and the total time was longer when the flatrack was on the vehicle. The higher loading time could be attributed to a higher lift that the RTFL operators had to perform in placing the pallets up on the truck. If anything, their view of the pallet base was better at truck-bed height than when the flatrack was grounded, negating visual cues as a reason. The tie-down teams normally tossed the ratchet end of the tie-down straps over the loaded pallets, then secured the ends and tightened with the ratchet. On the ground, each person could work the strap end from the ground. With the load up on the vehicle, one person had to toss a pair of straps up and over the pallets, hook the plain ends into the flatrack, and then run around to the other side to hook the ratchet end and tighten. The other person remained on top of the pallets to drape each strap properly over the load. The task of clearing the pallet tops when tossing the cumbersome straps and the high reach required to operate the ratchet (more difficult for the shorter male and for the female TPs) all made for a considerably longer routine.

Teams

The analysis for the Teams yielded an F statistic, indicating that a significant difference exists for both load and secure times and for total time. This means that at least one of the eight team's performance was statistically different from at least one other team's performance. After observing the entire set of trials performed, there is no explanation that the experimenters could offer other than that some of the TP combinations comprising the teams appeared to have better coordination among their members than other combinations. It certainly was not a case of one or more individual TPs being a "bad apple" and disrupting the performance of a particular team, nor was the presence of female TPs on the teams considered a positive or negative contributor to performance.

Interactions

Only two interaction statistics showed significance in the analysis. These both occurred in the ANOVA for load times: Ammo x Posture and Posture x Team. Interaction effects may be attributable in part to the experimental treatments and in part to the variations caused by extraneous factors such as weather, muddy or dry ground conditions, and so forth (Lindquist, 1956). The Ammo x Posture interaction may exist because the truck-mounted flatracks, which generally took longer to load, took a substantially greater amount of time to load for artillery ammunition with its greater number of repetitive lifts, than when the flatracks were grounded. For the Posture x Team case, since the teams are already known to differ, the interaction may be present because at least one team took significantly longer to load flatracks up on the truck, regardless of ammunition type. The team effect in this instance is probably attributable to only the forklift driver and the guide (Snedecor & Cochran, 1967).

CONCLUSIONS

The mean times that appear in Table 4 may serve as base line information in regard to the uploading of ammunition on PLS transportation.

In moving ammunition forward from CSA or ASP, it would appear on the surface that loading PLS trucks and PLS trailers (assuming that they are present and available for loading when they need to be loaded) would directly expedite the flow of ammunition better than if PLS flatracks were grounded before loading. The results of these field trials would indicate otherwise. Ammunition issue operations apparently could be accomplished somewhat faster if the flatracks were available for uploading even if the trucks or trailers were unavailable. These results therefore strengthen the case for having a pool of empty flatracks available at the CSA and ASP supply nodes, ready to be loaded upon receipt of a shipping order, rather than waiting on the convoy of PLS trucks to arrive to begin loading operations. To keep such a system functioning properly, the arriving PLS assets would be required to have empty flatracks aboard to replenish the pool. Retrograde of the flatracks is an essential part of any system employing PLS.

Given that the information, listing the ammunition requirements for a particular unit's resupply operation, arrives at the CSA or ASP node sufficiently before the arrival of the transportation assets, the arranging of that unit's ammunition into UCLs is an obvious benefit to the resupply system at the user's end. The fact that making up flatrack loads of UCLs does not appear to detract from the uploading operation at the node, is a plus for the employment of UCLs.

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