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Adjustable Field Hospital Bed: Effects of Prototype Leg Braces on Stability, Load-Bearing Capacity, and Rough Terrain Use

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The Adjustable Field Hospital Bed consists of a collapsible lightweight aluminum frame with a nylon patient support fabric. A Deployable Medical Systems (DEPMEDS) evaluation identified three potential problems: general stability, use on uneven terrain, and strength to support Cardiopulmonary Resuscitation (CPR). The USABRDL was requested to evaluate the above concerns and provide practical solutions for deficiencies found. Although the bed meets current specifications, a comparison of stability with and without simple corner braces designed by the USABRDL revealed that significant improvement could be achieved. The bed was found to accommodate moderately uneven terrain in both braced and unbraced conditions by flexing under load. Static and dynamic load-bearing tests confirmed the bed's ability to withstand expected stresses during CPR. Even though the prototype braces only slightly improved the loadbearing capacity, the stabilizing effect allows the CPR administrator to more closely maintain the recommended frequency and direction of CPR actions. The results of this evaluation suggest the prototype braces be optimized for field use and be provided as an accessory package.

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INTRODUCTION

The Adjustable Bed (Figure 1), developed for military field hospitals, consists of a lightweight, aluminum frame with nylon patient support fabric. Configured for use, the bed is 82 inches long, 30 inches wide, and 28 inches high. Patient support is adjustable by hand to 70 degrees above horizontal. The bed weighs 28 pounds and can be folded for transport and storage. Two flexible steel cables support the bed and provide load bearing capability. The folding feature and light weight are ideal for field hospitals, but make the bed inherently less stable than conventional designs. Three potential problems were cited in an assessment report on the bed: general stability, adjustment for uneven terrain, and sufficient strength to support Cardiopulmonary Resuscitation (CPR) (Academy of Health Sciences, U.S. Army 1989). The U.S. Army Biomedical Research and Development Laboratory was requested to evaluate the above concerns and provide practical improvements for any deficiencies found.

This report presents a quantitative comparison of stability and load-bearing capacity with and without prototype stabilizing braces designed by this Laboratory. An assessment of the bed's ability to accommodate uneven terrain is also presented. Each brace assembly (Figure 2) weighs 14 ounces and two assemblies per bed are required. Although the current prototype braces require tools for installation, the final design would have clamps on the free ends of the rods and hinged joints between the rods and foot cup. This design would allow tool-free installation and would permit collapsed brace assemblies to be packaged inside the folded bed with no increase in volume.

METHODS AND MATERIALS

All tests were conducted on a bed that was confirmed to meet current specification requirements for stability and load bearing capacity (U.S. Army 1978). Tests were conducted on a smooth, hard, flat floor with a one eighth inch thick rubber pad under each foot of the bed to prevent sliding.

Stability tests were designed to determine the bed's horizontal rigidity and downward deflection under load for both braced and unbraced conditions. The braced condition consisted of one brace assembly installed at each of two diagonally opposite corners. Transverse and longitudinal displacements of the bed were measured for a horizontally applied force of 50 pounds (to simulate accidental bumping of the bed) and a simulated patient load of 200 pounds representing the 95th percentile U.S. Army male (U.S. Army Human Engineering Laboratory 1981). Horizontal forces were applied to the bed at the hinge on one side, and in the center of one end with a 0-50 pound mechanical force gauge (Model IN-50, Chatillon & Sons, Greensboro, NC). Pointers attached to the bed on the side and end opposite the force gauge were used to indicate displacement on a 12 inch steel rule mounted on an adjustable floor stand. A 9 inch diameter, 60 inch long sand bag provided the 200 pound simulated patient load.

Downward deflection of the bed was measured as 500 pounds was loaded in 100 pounds increments onto a 2 inch by 6 inch by 48 inch wood plank arranged across the bed at the center hinges. The weight was chosen as a worst case test load of 2 1/2 times the weight of the 95th percentile U.S. Army male. The bed was loaded across the center hinges because cable tension is directly related to effective center load and a supine patient applies only a portion of total body weight to the center of the bed. The downward displacement of the bed was measured at the center hinge on each side and deflection taken as the mean of the two measurements.

The bed's ability to accommodate uneven terrain was determined by adding 1/4 inch spacers, one at a time, under an unbraced leg until the entire weight of the bed was borne by that leg and the one diagonally opposite. At this point the other two legs supported none of the load and served only to balance the bed on the two loaded legs. This test was conducted with no load and with a 150 pound load, chosen for convenience of testing.

Load-bearing characteristics of the bed were determined for both static and dynamic loading situations in unbraced and braced configurations. Since the steel cables support the load on the bed at the center hinges, cable breaking strength indicates the load-bearing capacity. A tension/compression load cell (Model SM-1000, Interface, Inc., Scottsdale, AZ) was spliced into one of the support cables and excited with a bench power supply (Model 6215A, Hewlett Packard Co., Palo Alto, CA). For the static loading situation, weights were placed on the bed in the same manner as for downward deflection while load cell voltage was measured with a digital voltmeter (Model 8000A, John Fluke Mfg. Co., Inc., Seattle, WA).

The dynamic loading test was designed to give an indication of the bed's ability to withstand stresses expected during CPR. Cable tension was continuously monitored with a strip chart recorder (Type 2025 with Type G8045 amplifier, Linseis, Princeton-Jct., NJ) during simulated CPR. Two possible

CPR techniques were tested. CPR was performed on a simulated patient (200 pound sand bag) by a 170 pound, trained CPR administrator while standing beside the bed and while kneeling on the hinges of the bed straddling the sandbag.

RESULTS

The 50 pound horizontal force produced a longitudinal displacement of 1/2 inch and 1/16 inch on the unbraced and braced beds respectively. Lateral displacement was 11/32 inch for the unbraced bed and 3/32 inch for the braced bed. These data show that braces reduce longitudinal displacement by 87 percent and lateral displacement by 73 percent.

At a 500 pound load, the downward deflection was 1 11/16 inch and 1 15/32 inch for the unbraced and braced beds respectively. Deflection did not increase over a 30 minute time period and both beds returned to original height when unloaded. None of the bed components failed during loading tests.

In both unbraced and braced conditions the bed frame flexed to accommodate spacers placed under a leg. With no load, unbraced and braced beds were able to compensate for 3/4 inch and 1 inch respectively before the opposite pair of legs were unloaded. With a 150 pound load, the unbraced bed withstood 3 1/4 inches and the braced bed withstood 3 1/2 inches of spacers. Stability measurements were not taken with spacers in place.

Cable tension versus static load is shown in Figure 3. For the 200 pound simulated patient, cable tension was 183 pounds (19 percent of 982 pound cable breaking strength). For the same test conditions the braces reduced the cable tension to 157 pounds (16 percent of cable breaking strength).

A recording of cable tension during dynamic loading (CPR) is shown in Figure 4. Peak tension in the cable during either method of CPR was 330 pounds (33 percent of cable breaking strength) for the unbraced bed and 255 pounds (26 percent of cable breaking strength) for the braced bed. Excursions of cable tension are also significantly reduced by the braces.

DISCUSSION

Although the unbraced bed meets current specifications for stability and load bearing capacity, simple corner braces can be used to significantly improve stability. The addition of corner braces had little effect on the static or dynamic load-bearing capacity. The unbraced bed was found fully capable of withstanding the stresses incurred by structural members during static loading and CPR. The substantially increased rigidity of the braced bed, however, gives the CPR administrator confidence in the bed's ability to support the task and makes it possible to more closely maintain the recommended frequency and direction of the CPR action. The braces had little effect on the bed's ability to accommodate uneven terrain. In both configurations the bed compensated for moderately uneven terrain by flexing under load. Should the bed be used in extremely uneven terrain or if the user requires an active leveling capability, significant design changes or development of separate leveling devices would be necessary.

CONCLUSIONS AND RECOMMENDATIONS

The prototype braces should be optimized for field use and made available as an accessory package. Optimization should address designs that allow folding for packaging and tool-free installation.

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Academy of Health Sciences, U.S. Army. memorandum, HSHA-CDM, DEPMEDS assessment issue A-50 title: Hospital bed improvements. 1 December 1988.

U.S. Army Human Engineering Laboratory. 1981. Human factors engineering design for Army materiel, MIL-HDBK-759A.

ADJUSTABLE BED
NSN 6530-01-015-5189

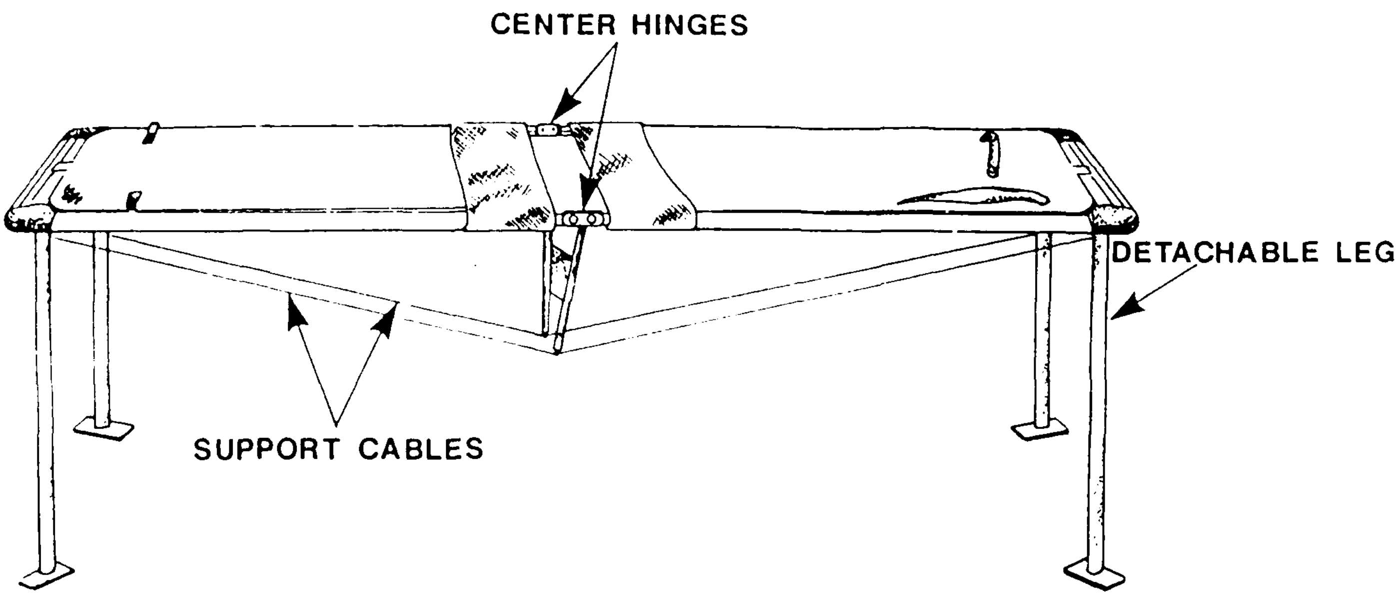
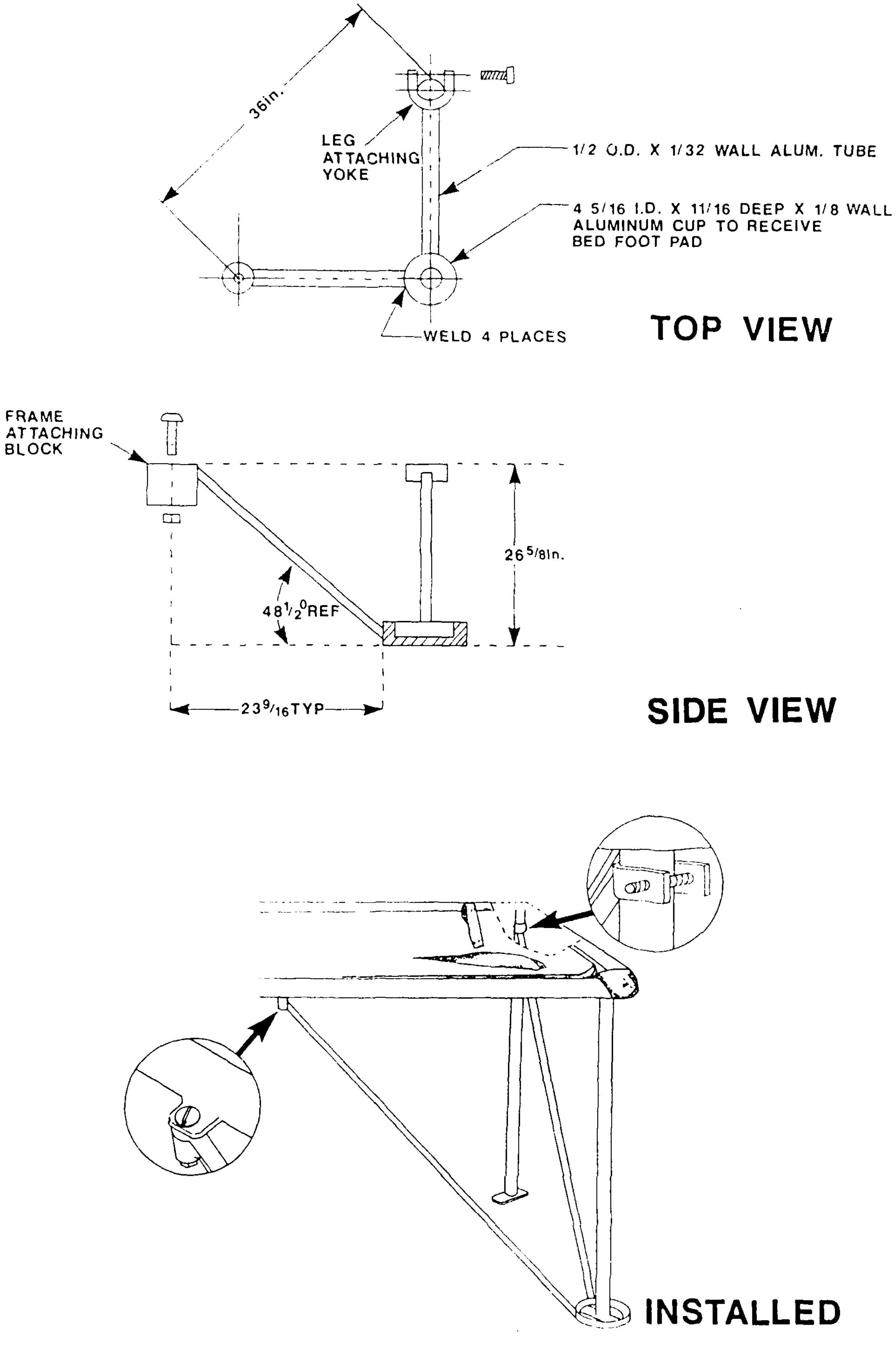


FIG. 1



BRACE ASSEMBLY

FIG. 2

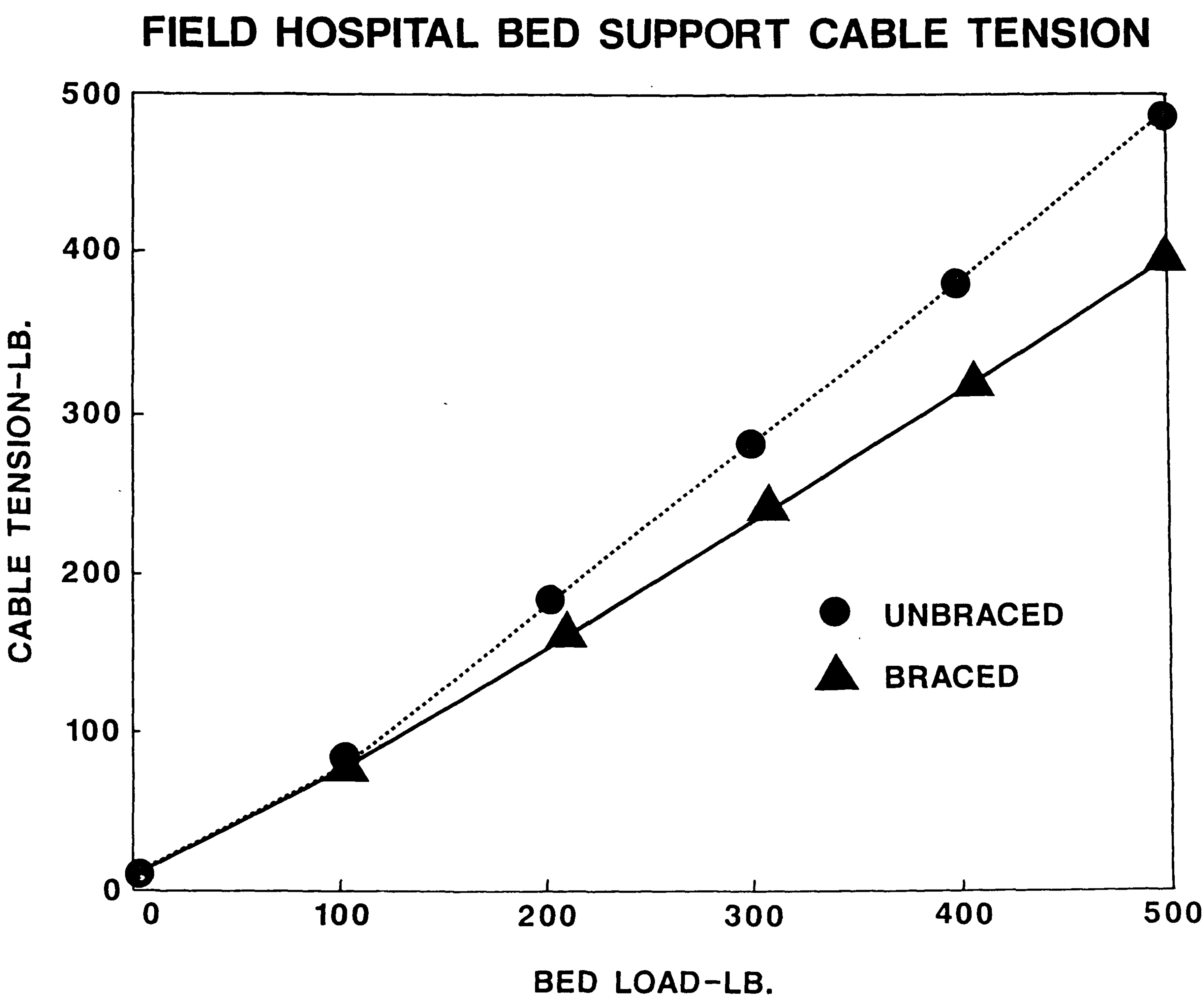

FIELD HOSPITAL BED SUPPORT CABLE TENSION
CABLE TENSION-LB.
0
100
200
300
400
500
BED LOAD-LB.
UNBRACED
BRACED

FIG. 3

ADJUSTABLE BED SUPPORT CABLE TENSION DURING CPR

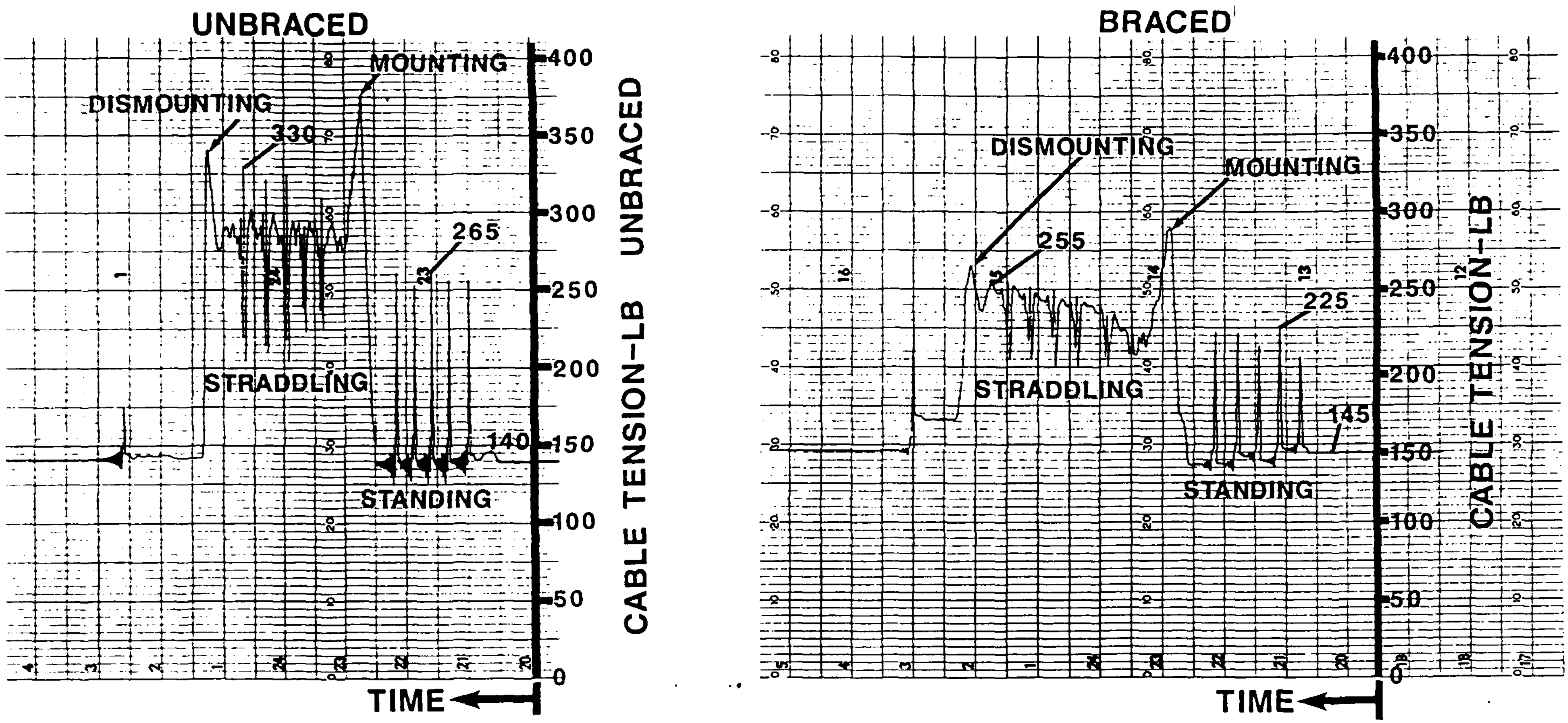


FIG. 4

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