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THE USE OF FIELD EXPEDIENT ARMOR

REVISION 1

By:

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December 1965

U. S. ARMY LIMITED WAR LABORATORY

Aberdeen Proving Ground, Maryland 21005

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INTRODUCTION

This manual is for the use of personnel in the field, especially those in remote jungle areas engaged in counter-guerrilla warfare, who require armor for a vehicle or post for protection against ambush attacks. Indigenous armor materials are usually available but adapting them to a vehicle or ground position is often the problem.

The armor designs described below will withstand that first close-in small arms fire and provide the 30 seconds protection needed to take the necessary counter measures. This armor is not designed for permanent protection, nor in most cases for stopping any round in excess of caliber .30 ball, except where the use of two or more layers of the armor may protect against caliber .30 AP or larger ammunition.

Two points to remember are: 1) Do not exceed the cross-country carrying capacity of the vehicle you intend to armor unless you have helper springs to relieve the overload, and 2) the careful choice of materials can save overall weight for the armor kit. For example, a caliber .30 M1 ball bullet will penetrate up to 8" of gravel (weighing about 80 lbs/sq ft), and yet, it can be defeated by a box made of 1-1/4" teak wood filled with 3" of gravel (at 37 lbs/cu ft). When we consider the 3' x 12' sides of a truck bed this represents a saving of at least 2 tons.

Table I provides bullet stopping data for indigenous and low cost commercial armor composites. These data show, for example, that pound for pound, Vietnamese clay tile bonded to an adequate wood backing is as efficient as standard steel armor plate in providing bullet protection.

In preparing indigenous or field-expedient armor the simplest procedure is to: 1) Assemble convenient sized sections of wood or other back-up materials (i.e., Bombax or fibre boards), 2) glue tiles or similar hard faced materials to the front, and 3) then mount the "armor" to the vehicle or fortification being sure the hard-faced material or tile is toward the enemy.

TABLE I

Commercial Lightweight and Indigenous Armor Materials
Required to Stop a Caliber .30 Ball Bullet at Ten (10) Meters

	MATERIALS			Total Thickness	Nominal Unit Wt Lbs/Sq Ft
	Face	Filler	Back-Up		
1.	High Hard Steel (Brinell 510)	--		1/4"	10
2.	Bullet Resistent Glass (NOTE A)	--		2-1/4"	18
3.	3/4" US Clay Tile (NOTE B)	--	12" Balsa	12-3/4"	16
4.	3/4" US Clay Tile	--	3" Teak	3-3/4"	18
5.	3/4" US Clay Tile	--	5" Bombax (NOTE C)	5-3/4"	19
6.	3/4" US Clay Tile	--	3" Bagasse (NOTE D)	3-3/4"	19
7.	1" VN Clay Tile	--	5" Bombax	6"	21
8.	1-1/8" Teak	3" Gravel (NOTE E)	1-1/8" Teak	5-1/4"	37
9.	2-1/8" Bombax	2-1/2" Gravel	2-1/8" Bombax	6-3/4"	38
10.	1-3/8" Bombax	3-5/8" Brick	1-3/8" Bombax	6-1/2"	52
11.	1" Pine	6" Sand	1" Pine	8"	58
12.	1" Pine	5" Trap Rock (NOTE F)	1" Pine	7"	59
13.	Burlap Sack	7" Trap Rock	--	7"	66
14.	Burlap Sack	8" Sand	--	8"	71
15.	Burlap Sack	16" Earth	--	16"	100

NOTE: A. A glass faced plastic laminate made by Safetee Glass Corp., Philadelphia, Pennsylvania.
B. Red Common Clay Hearth or Quarry Tiles of the type which might be produced in Southeast Asia.
C. Also known as Fromager; US Trade Name: Corissa.
D. Fibre boards made from bagasse, i.e., spent sugar cane waste.
E. The size of the gravel was 1/2" to 2".
F. Trap rock (crushed stone) and larger gravel, 1-1/2" to 3" diameter.

Further information about these materials is shown in Appendix I. Note that there is quite a weight penalty in using boxes and burlap bags filled with gravel, sand or brick (items 8-14) over the tile-wood laminate (items 3-7). However, these boxes and bags have the advantage of defeating a greater number of bullet impacts per square foot than is possible with clay tiles with wood backing. The box containing bricks stacked on end (item 10) even withstood three ball bullet impacts into the same point on the box; only the fourth round impact caused the back of the box to tear away at the nails. The same holds true for sand filled bags and to a lesser extent rock filled bags - the latter have a tendency to tear.

With the tile-wood laminates, even though only a portion of the tile is shattered on impact, the rest of the tile is weakened to subsequent hits and can probably sustain only about 6 to 8 hits per square foot before it is penetrated. The gravel filled box, however, with 2" to 3" wood backing will sustain a greater number of hits since: a) the gravel or stones which are hit and broken up by one bullet, will shift and allow other pieces to fill the void, and b) the thicker wood backing is not as prone to splitting and finally rupturing after 3 or 4 hits. In the 1" pine box, it is always the box back which gives before the sand or gravel filler has outlived its usefulness. For convenience of handling and placement, the gravel filled wood "armor" boxes may be made up of one foot square boxes, rather than one or more large boxes which would be more than one man could handle.

Small pea gravel lacks the effectiveness of larger gravel (1/2" to 2") and trap rock (crushed stone), since a bullet must be stopped by something comparable to its own mass for effective momentum transfer. Thus, brick or clay tile, when contained, will stop additional bullets as long as the remaining fragments match the mass of the impacting projectile. Soil or earth in burlap bags is not very effective against multiple hits, since it tends to pack and lose its effectiveness thereby.

The best commercial US bonding agent tested with the tile-wood laminate, which minimized tile spalling after bullet impact, was Minnesota Mining and Manufacturing Corp. CTA-11, which needs no catalyst. This agent provides about 90% tile retention after bullet impact. However, if no good glue is available use whatever bonding agent is on hand and tie, stake or nail (but do not glue) a canvas or thin wood cover in front of the tile to prevent the impacted pieces from falling off. A good fish base or animal base glue may be available for your use locally.

Teak wood is comparable to Bombax wood in the weight of material required as tile back-up or for gravel filled boxes. However, it is not as desirable to use as Bombax, fibre board or balsa. First, it is more difficult to cut and nail; secondly, it has a much greater tendency to split.

Balsa wood, although a good, lightweight armor back-up, is limited by the narrow widths in which the board is normally supplied and by the 10" to 12" thickness required to back up the tile. Although the pieces may be glued together readily, the bulk of such an armor may rule it out for vehicle armor when other materials are available. In the absence of something better, however, it will provide satisfactory protection for a limited time, as will ordinary pine boards from packing boxes.

The fromager or Bombax wood, which has been shown in indigenous armor tests to be so effective, is usually found in Darlac, Quang Duc and Tuyen Duc provinces of Vietnam and to some extent in Ba Xuyen and Vinh Binh. Pottery and tiles are found largely in Quang Duc, but are also made locally in many places. Some timber is processed on French owned plantations throughout Vietnam. This type of wood is also found in virgin and secondary forests in hills and swamps with fertile soil of Africa, Central America, Burma, Malaya, and other areas of SE Asia.

Bagasse fibre board, the back-up material in item 6, Table I, is made in the US. It is not available in Vietnam, but local manufacture of a fibre board made of similar material such as Brazilian Reed, wild African canuf grass or shredded, dried and crushed bamboo or cocoanut fibres will work as well.

To show what can be done in armoring a 2½ ton truck with a modular steel plate kit see Figure 1 and 2. Indigenous armor is shown in Figure 3 for the body sides, and high-hardness steel for the rest of the truck. A set of template drawings for a modular steel armor kit is inclosed in Appendix II, should steel be available.

The relatively new XAR-30 high hardness steel noted in this report is a rolled, homogenous steel plate, heat-treated to a Brinell hardness of 480 to 530 - hence, high hard. It is commercially available and is now being used in Vietnam. Its main draw-back is that it is difficult to drill or cut. In fact, it cannot be sheared on standard equipment. The procedures for modifying high-hard steel plates are shown in Appendix III.

It must be remembered also that all of the materials described above, except steel, have a limited useful life under attack. Indigenous armor can usually withstand only 6 to 8 ball bullet impacts per square foot. However, it should provide enough bullet stopping capability to dull the effectiveness of that first burst of enemy small arms fire which opens almost every enemy ambush. The time thus gained for troops on board indigenous-armored trucks will permit them to detruck and take necessary counter-measures.

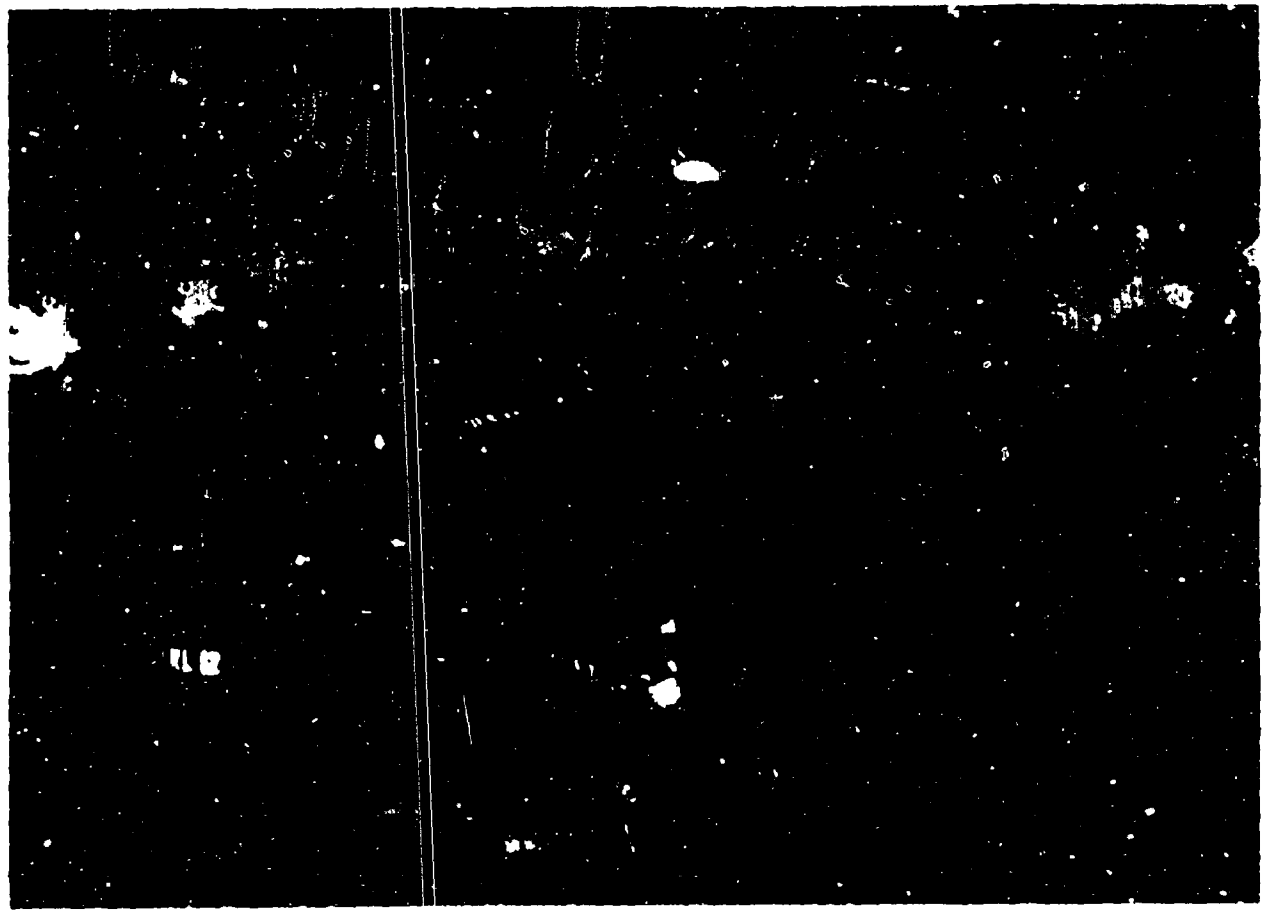


Figure 1. 2½ ton Truck with Modular Armor Kit - Front right 3/4 view.

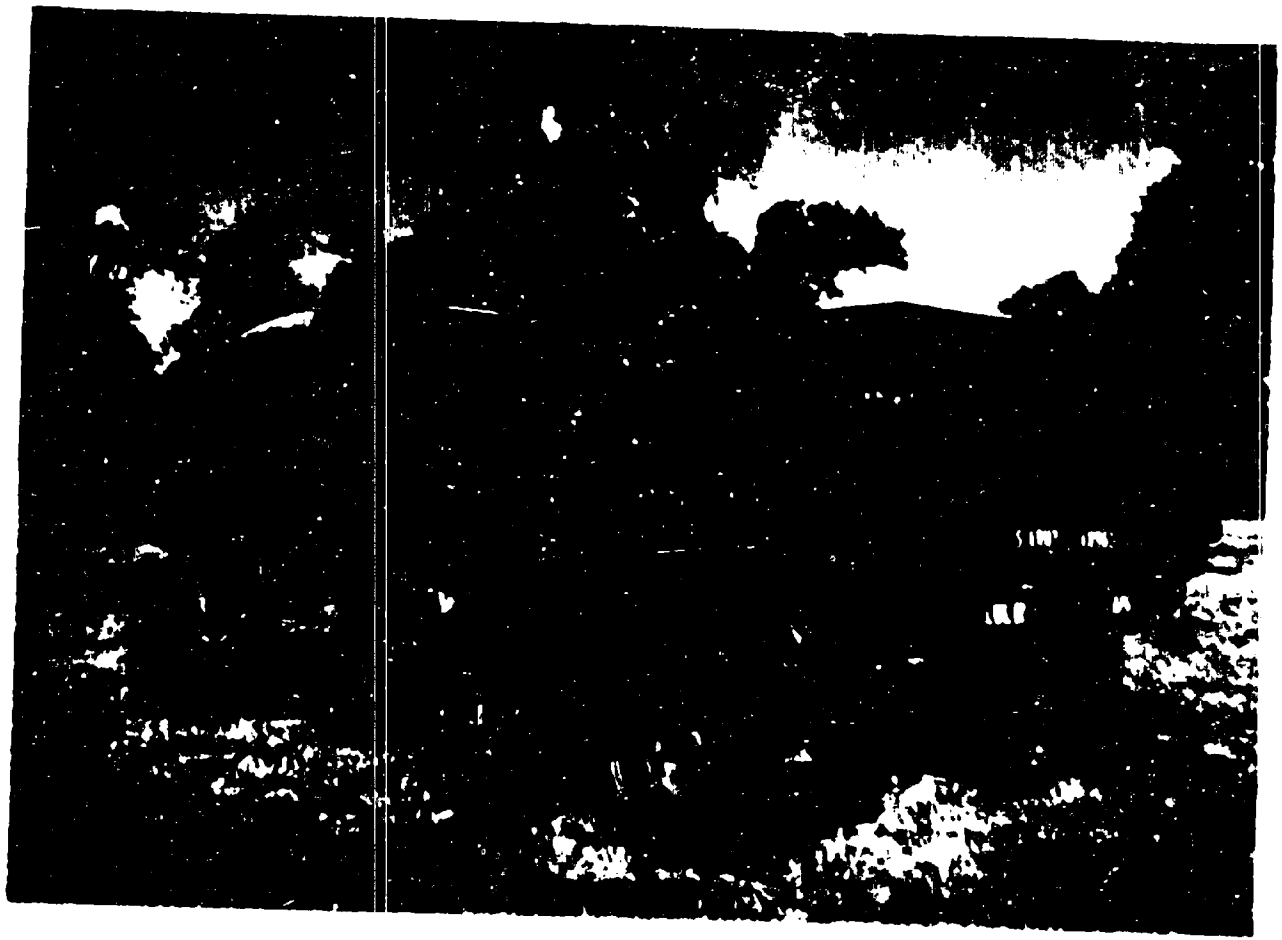


Figure 2. 2½ Ton Truck with Modular Armor Kit - Rear left 3/4 view.

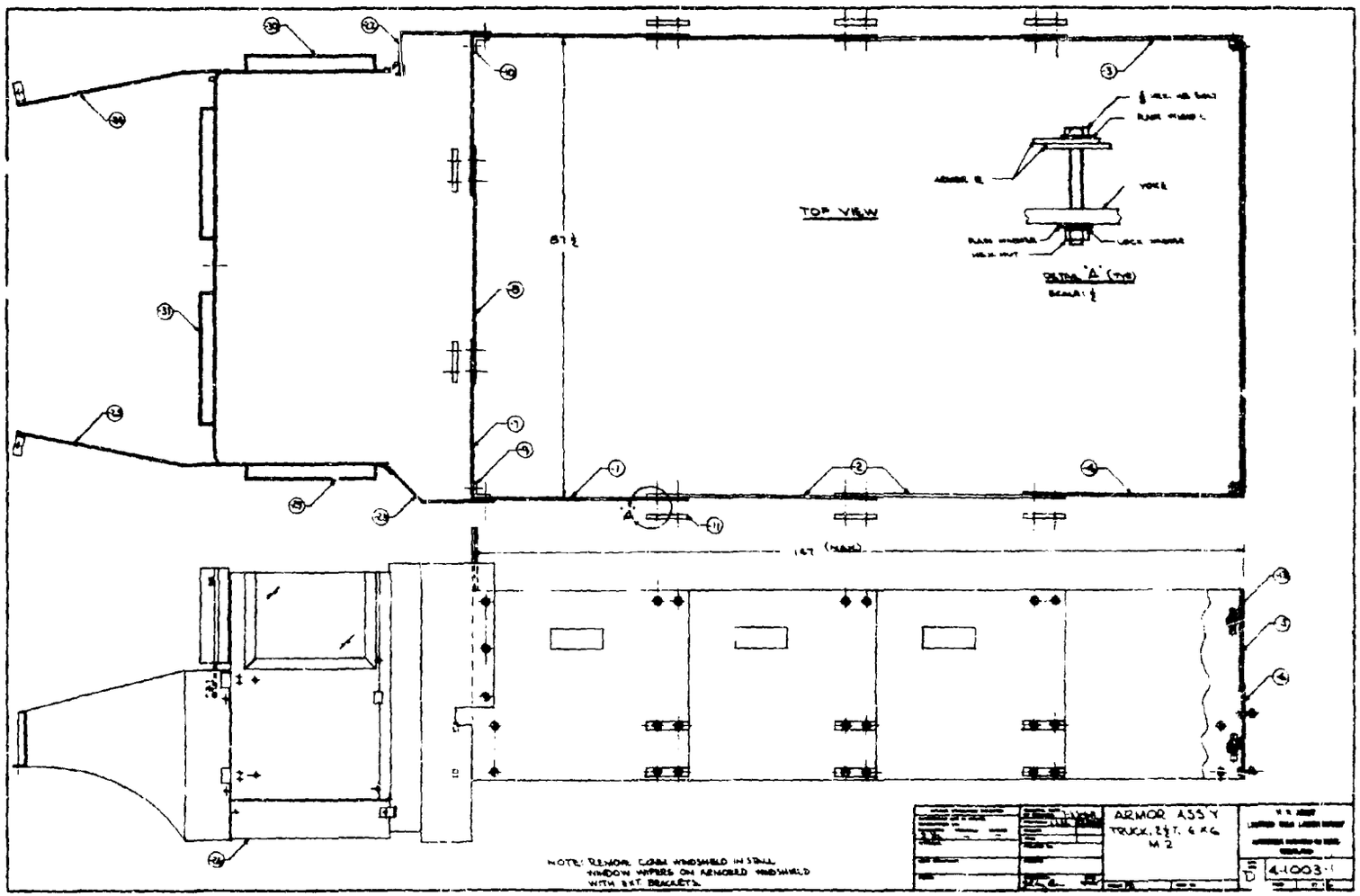
Figure 3. 2½ ton M211 Truck showing ¼" XAR-30 High Hardness Steel on cab and tailgate; Body sides are armored with clay tile bonded to Bombax Wood.

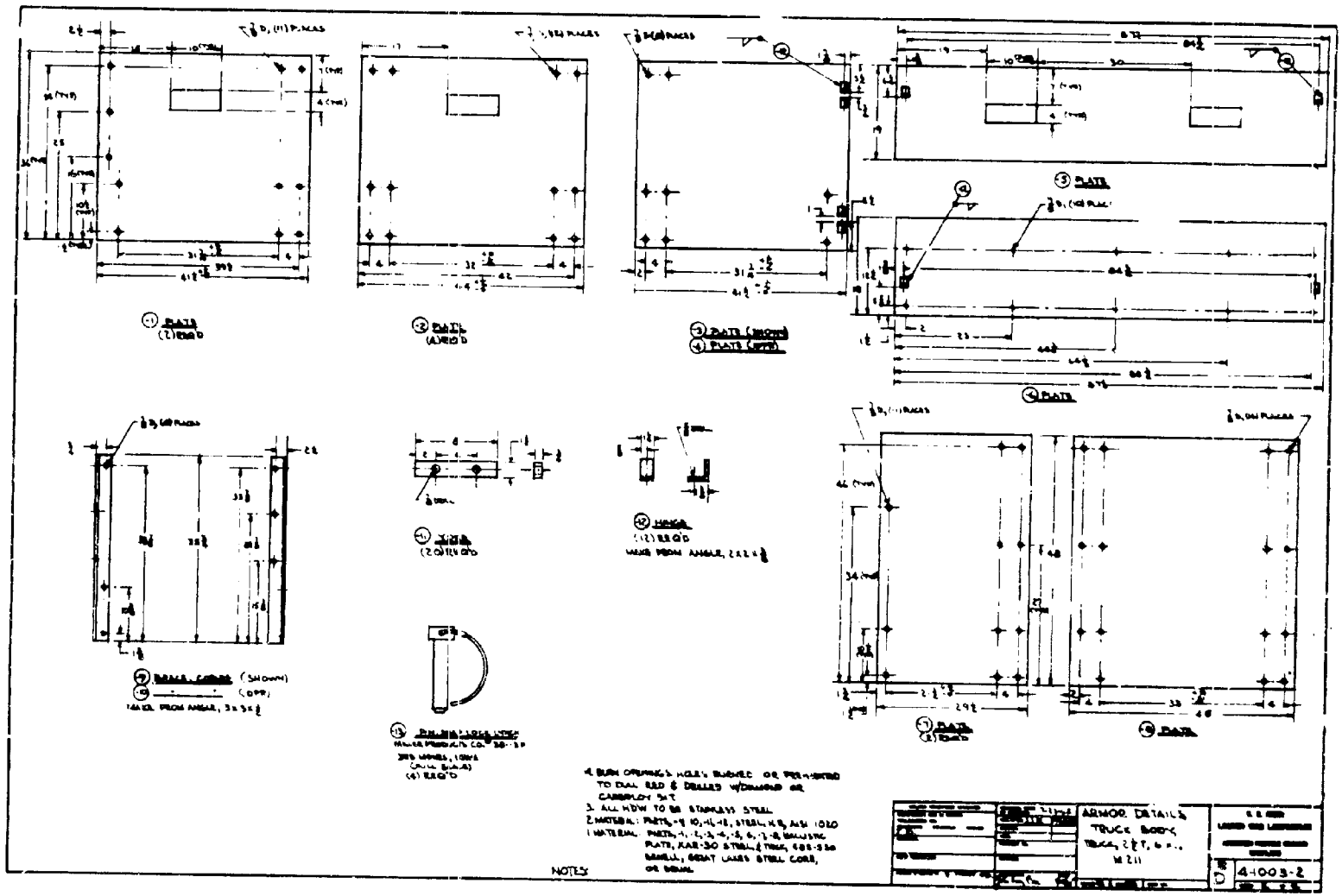
If you have to protect against a higher threat level than .30 ball ammunition, as for example .30 armor piercing - this may be accomplished with two layers of that 1/4" high hard steel, spaced 1/2" apart. Also, 7" sand bags or 8" rock filled bags protect against AP as well as ball bullets.

APPENDIX I

DESCRIPTION & USAGE OF ARMOR AND ARMOR BACK-UP OR FILLER MATERIALS FOR USE ON TRUCKS

MATERIALS	DESCRIPTION	THICKNESS USED & UNIT WEIGHT	SIZE RANGE	DURABILITY	WORKABILITY
Bombax Malabaricum Back-Up	Also known as Ceiba Pentandra, Ceibo, Fromager, Silk-Cotton Tree, Bonga, Corkwood or Pochote. Trade Name: CORISSA.	5" = 11#/sq ft	Trees up to 150' high and 7' diam. with buttress roots.	Very low resistance to decay, discoloration, while rot fungus and insect attack.	Easily worked and sawn along grain. Machining and cross-cutting poor with wooly surfaces.
Cheesewood	Ceibo, Assacu.				Sawyers became violently ill from this wood.
FIBRON (trade name) Back-Up	Fortified Bagasse Panel Board (of compressed, spent sugar cane wastes.)	4 x 3/4" = 11#/sq ft	Up to 5' x 20'	Good resistance to fire, mold, fungi and termites. Four percent (4%) swell after 24-hour soak.	Easily machined with wood tools. Easily bonded.
Balsa wood Back-Up	Grade A Clear Grade B Common Bombacaceae, Ochroma Lagopus, also known as Down-Tree or Cork-Wood.	12" - 8#/sq ft	1/2" to 3" thick width 3" & up length 3' & up	Good	Easily worked
Teak wood Back-Up	Verbenaceae, Tectona grandis.	3" - 10#/sq ft		Excellent	Good, but has tendency to split.
Hearth Tile Facing	Red Common Clay Tile, also known as Quarry Tile.	3/4" - 8#/sq ft	6" x 6"	Excellent	Readily bonded to armor back-up.
Gravel Box Filler	Pebbles 1/2" to 2" size (not trap rock or crushed stone.)	2-1/2" to 3" = 19 to 25#/sq ft		Excellent	Easily loaded into containers.
Bricks Box Filler	Common baked clay bricks	3-5/8" = 41#/sq ft	2-1/4" x 8-1/8"	Excellent	Easily stacked.
Steel Armor	High Hardness Ballistic Plate, Brinell 485 - 530	1/4" = 10#/sq ft	Up to 6' x 12'	Tends to rust if unprotected.	Cannot be cut or drilled. Must be burned to shape.
Safety Glass Armor	Bonded glass-plastic laminate.	2-1/4" = 17#/sq ft		Excellent	Must be fabricated to size at plant.

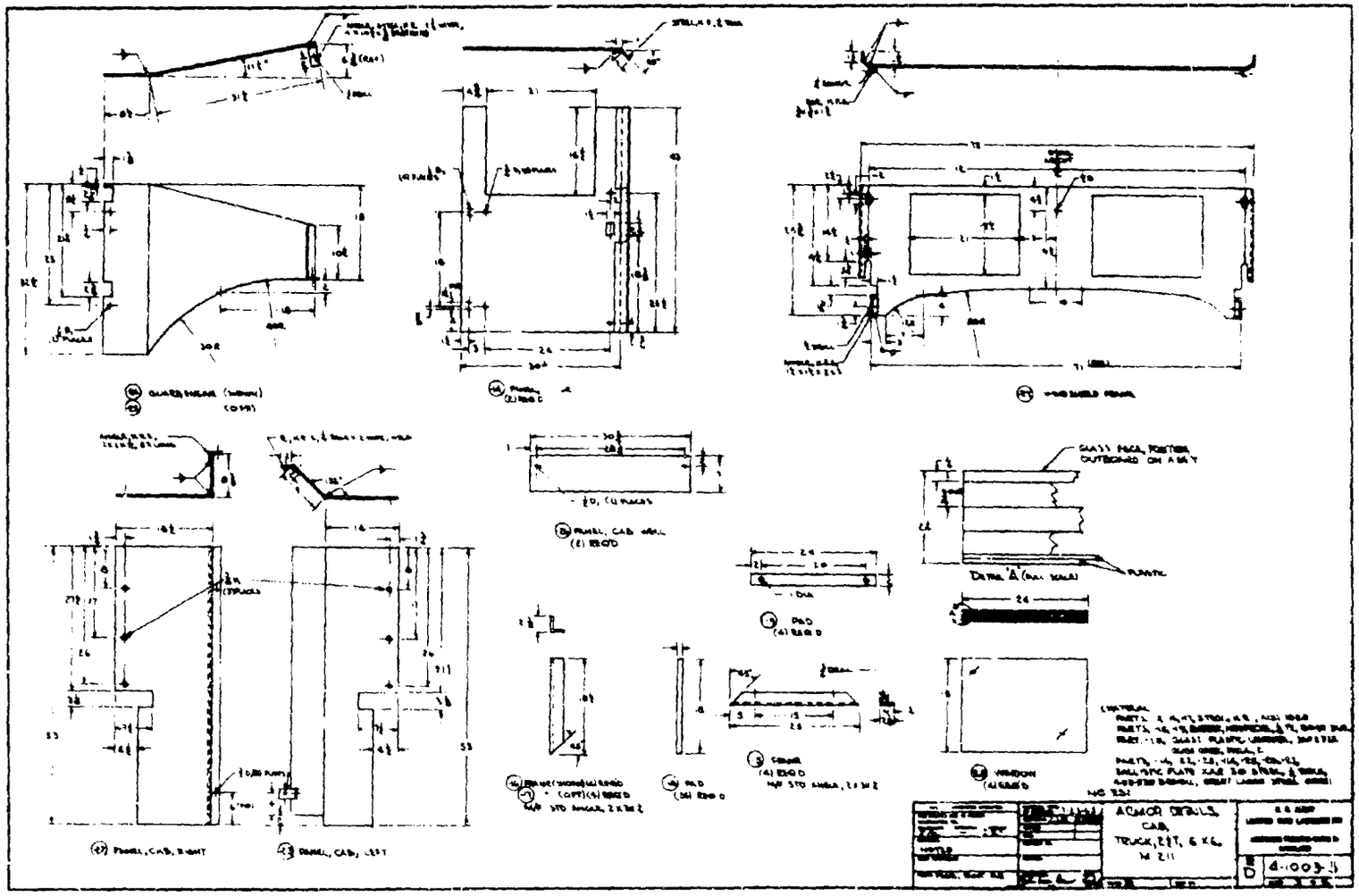

TOP VIEW
DETAIL 'A' (TYP)
87½
167 (MAX)
ARMOR ASSY
TRUCK, 2½T, 6 X 6
M 2
4-1003-1
NOTE: REMOVE CLOTH WINDSHIELD INSTALL
WINDOW WIPERS ON ARMORED WINDSHIELD
WITH BRACKETS.

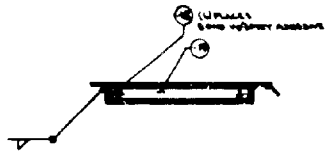


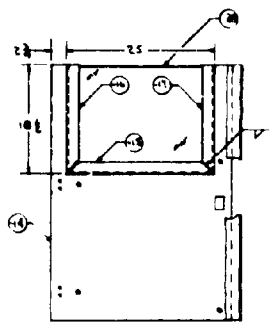
NOTES:

4. BURN OPENINGS, HOLES, BUSHED OR PUNCHED TO FINAL SIZE & DRILLED WORKMANSHIP OR CAMPBELL'S "T"
3. ALL HDW TO BE STAINLESS STEEL
2. MATERIAL: PARTS, -9 10, -11, -12, STEEL, H.B. AISI 1020
1. MATERIAL: PARTS, -1, -2, -3, -4, -5, 6, -7, -8, BALLISTIC PLATE, XAR-30 STEEL, TRUE, 485-534 BRINELL, GREAT LAKES STEEL CORP, OR EQUAL

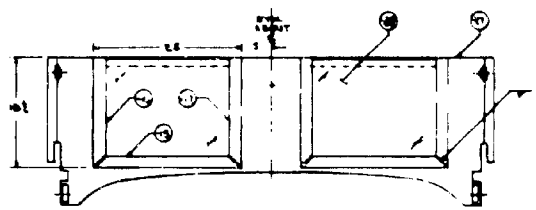
ARMOR DETAILS TRUCK BODY, TRUCK, 2½ T, 6 x ... M 211	4-1003-2


ARMOR DETAILS, CAB, TRUCK, 2½T, 6 X 6, W 211
4-1003-11





DOOR ASSY (SHOWN)
(OPP)



WINDSHIELD ASSY

ARMOR SUBASSYS
TRUCK, 2½T, 6 × 6,
M2...

4-003-4

APPENDIX III

PROCESSING TECHNIQUES FOR XAR-30 HIGH HARD STEEL

CUTTING: The XAR-30 may be sectioned with a cutting torch at any time, but preferably in the as-received condition. For straight cuts, especially on larger sheets a motor driven cutting head (torch) should be used. After burning larger sheets may need straightening - using pressure only!

FINISHING: After cutting with hand or motorized cutting torch, edges should be de-burred by disc grinding. Where new sheets have been cut, they should be sand-blasted to remove the scale, coated with Metal Prep or other acid surface etch, then with a phosphate type prime coat and finally with an enamel.

BENDING: XAR-30 can be bent, but this should again be done in the "as-received" condition. (Bending 1/4" XAR-30 will require a 100-ton press.) Any scratches on the surface to be bent, even as small as grinding disc marks will cause the material to break. For all radii required a smaller bending radius must be used to allow for spring back.

DRILLING: To make a hole in XAR-30 steel it may be burned all the way through with a torch or pre-heated and drilled. Without treatment a carbolloy drill will make up to three holes before it needs sharpening. By preheating the area to be drilled with an acetylene torch to a "Dull red" (NOT cherry red!) up to six holes may be drilled. Better results may be obtaine with a commercial diamond drill bit or a Laser. An area heated dull red will attain a hardness of 35 Rockwell C, whereas heated cherry red it will quickly return to the normal high hard condition of 51 R. C.