FIRE BLOCKING BLANKET FOR PROTECTION OF STORED AMMUNITION

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ABSTRACT

Munitions stored in the open are vulnerable to a multitude of external threats that can lead to their detonation. Stacks of munitions stored in close proximity to one another are particularly vulnerable in that the deflagration of one stack may promote the deflagration or detonation of one or more of its neighbors. This article describes the development and demonstration of a protective fire blocking blanket for the prevention of propagation of reactions and fire between pallets of stored ammunition. When placed over the platform, this blanket serves as a barricade to prevent penetration of hot fragments, flame and low velocity projectiles from reaching and detonating the contents beneath. The blanket design is being engineered and optimized for field deployment by the Oak Ridge National Laboratory under a program conducted by the Logistics Research & Engineering Directorate, U. S. Army Armament Research, Development and Engineering Center. Program scope includes the manufacture by a commercial sewing contractor of full-size prototypes which will be evaluated later this year under realistic field test conditions. A summary of these activities and of studies conducted in support of material selection for this program are presented.

1. INTRODUCTION

Munitions stored in the open are vulnerable to a multitude of external threats that can lead to their detonation. Various mechanisms that may cause detonation include fire propagation, projectile impact, and blast pressure. Stacks of munitions stored in close proximity to one another are particularly vulnerable in that the deflagration of one stack may promote the deflagration or detonation of one or more of its neighbors. Depending on stack proximity, this series of events can propagate like dominos, destroying an entire ammunition depot via a catastrophic chain reaction.

The Army Research Laboratory (ARL) developed an experimental flame and fragment resistant blanket consisting of aramid and ceramic fibers that, in sub-scale prototype form, successfully protected stored munitions [1, 2]. The ballistic performance of the blanket offered protection from 300 g and 454 g fragments with velocities of 140 m/s and 60 m/s respectively, and protected the stored material from propellant in contact with the blanket burning in excess of 2500°C for 10 seconds.

This article describes the development and demonstration of a protective fire blocking blanket (FBB) for the prevention of propagation of reactions and fire between pallets of stored ammunition. When placed over the platform and its contents, the blanket serves as a barricade to prevent penetration of hot fragments, flame and low velocity projectiles from reaching and detonating the contents beneath. The FBB is currently being engineered and optimized for field deployment by the Oak Ridge National Laboratory (ORNL) under a program conducted by the Logistics Research & Engineering Directorate (LRED), U. S. Army Armament Research, Development and Engineering Center (ARDEC) located at Picatinny Arsenal in New Jersey. The program builds on the earlier experimental work to produce a finished article that can be mass produced and deployed in the field.

Today's mandate for leaner and lighter fighting forces and shrinking resource dollars dictate that the FBB design be deployable with three different pallet platforms (CROP, M1 and 463L) employed by the U. S. military. Figure 1 shows a typical CROP (Container Roll In/Out Platform) that is both unloaded and fully loaded with boxes of ammunition. The shorter 463L platform is shown in Figure 2. Table 1 summarizes the stacked box volume requiring protection/coverage for fully loaded CROP, M1 and 463L platforms. These dimensions show that the maximum possible coverage to be provided by an FBB is for the M1 and CROP platforms, and is a box-shaped "envelope" that is roughly 5.6-m long x 2.3-m wide x 1.9-m high.

Lastly, the U. S. Army sets restrictions on the amount of weight that can be lifted and carried by soldiers performing deployment and assembly operations. The maximum lift (to 0.9 m above floor) and carry (<10 m) limit for the FBB was defined as a little over the summation of the limits for one male and one female working together, or roughly 59 kg.

This program's scope includes FBB material selection; design; the manufacture by a commercial sewing contractor of full-size prototypes; verification that the FBB meets the established ballistic and fire protection; and testing to evaluate the FBB performance under realistic field conditions. A summary of these activities and of studies conducted in support of material selection for this program are presented.

2. MATERIALS OF CONSTRUCTION

The FBB construction consists of multiple layers of materials specifically selected to defeat threats posed from high temperature exposures, fire, and/or projectile impact. These include layers of silica ceramic fabric and short silica fiber mat insulation for protection from flame and high temperatures, and Kevlar fabric layers for protection from low velocity projectiles. These are enclosed within a protective cover consisting of a polyvinyl chloride (PVC)-coated polyester fabric to enhance durability and provide protection from the elements for the blanket materials.

Figure 3 shows the materials and their lay-up through the thickness of the blanket. The stacking sequence of blanket material layers through the FBB thickness is symmetric. A description of each material and its selection criteria are presented in the following sections.

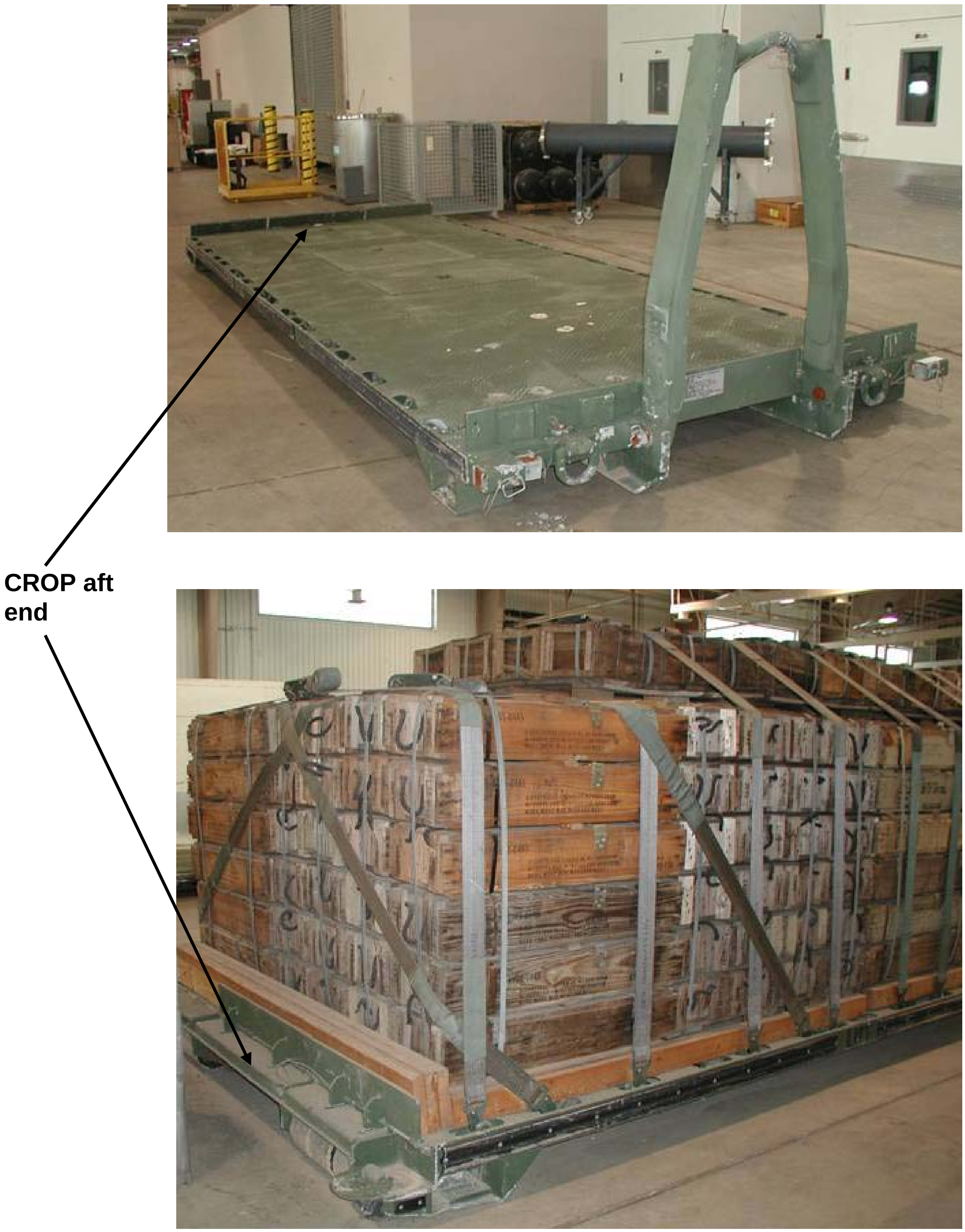


Figure 1. Unloaded and loaded CROP.

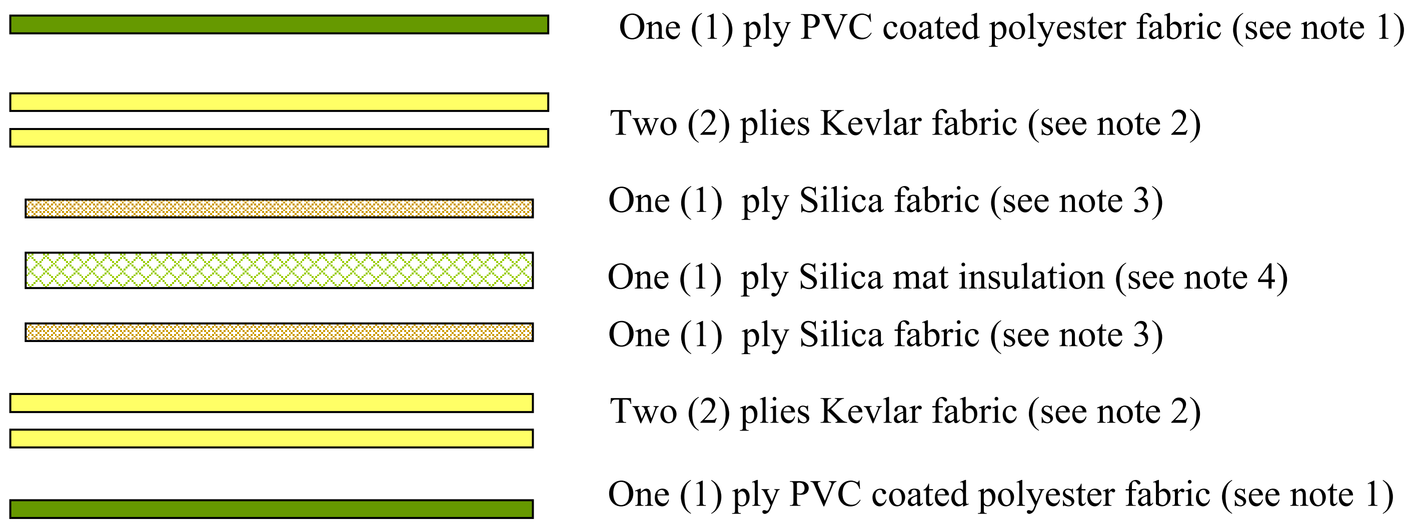
Figure 2. Loaded 463L platform.

Table 1. Dimensions for the CROP, 463L and M1 platforms.

Platform	Length (cm)	Width (cm)	Height Above Deck (cm)	Distance From Top of Deck To Ground (cm)
CROP cargo envelope	551	226	***187***	
CROP deck	592	***232***		26
463L cargo envelope	268	217	(See note 1)	
463L deck	268	217		6
M1 cargo envelope	***564***	230	174	
M1 deck	566	230		30

Notes:

1. The load on the 463L platform can be as high as 244 cm, but the platform only has a 4540 kg capacity. Realistically, almost all ammunition pallet units are less than 132 cm in height, so the CROP height is taken as the controlling height dimension for the blanket.
2. ***Controlling dimensions in bold italics.***



Note 1. Polyvinyl chloride (PVC) coated polyester fabric formulated for flame retardance and to be self extinguishing. Conforming to Mil-C-43006G and A-A-55308. Heat sealable. 576-610 g/m^2 areal weight.
Note 2. Style 745 Kevlar 29 fabric. 475 g/m^2 areal weight.
Note 3. Silica fabric. Amorphous silica ($\geq$ 94% pure silica, 9 micron fiber diameter) woven fabric. 0.76-mm. thick. 610 g/m^2 areal weight.
Note 4. Silica insulation. Amorphous silica ($\geq$ 94% pure silica, 9 micron fiber diameter) nominal 6.4-mm thick needle-punched mat insulation. 0.12-0.14 g/cm^3 density and 780-915 g/m^2 areal weight.

Figure 3. Fire blocking blanket materials and stacking sequence.

2.1 KEVLAR FABRIC

The Kevlar fabric refers to a Kevlar 29 Style 745 ballistic fabric with a nominal areal weight of 475 g/m^2 and a 0.6-mm ply thickness. It is a plain-woven, 17x17 construction, using 3000 denier yarn, and is used today in a number of personal protection applications, including car armor and cockpit door armor.

The Kevlar 29 Style 745 fabric was selected primarily because it performed reasonably well in ARL ballistic tests conducted as part of the FBB development program(1). In addition to its ballistic properties, Kevlar is an extremely rugged and inherently fire resistant material. Expectations are that the Kevlar outer plies will play a significant role in protecting the more fragile silica fabric and insulation materials sandwiched in between.

2.2 INORGANIC FIBER-BASED FABRIC

The primary function of the FBB is to block fire from initiating ammunition and other energetic materials stored on logistical platforms (CROP, M1 or 463L). Fire can initiate ammunition by the flame holing the blanket and impinging directly upon the ammunition or by the heat flux of the flame elevating the temperature of the ammunition behind the blanket. A criteria established by ARL was that the temperature behind the blanket could not increase more than 100°C above ambient. Maintaining temperatures at this level should not initiate the ammunition.

An inorganic fiber-based fabric serves as a heat shield to resist flame penetration. During the ARL FBB development phase, many different candidate fabrics woven from inorganic fabrics were evaluated, including fiberglass and ceramic fibers. Silica fabric was selected by ARL for their subscale prototype blanket manufacture and evaluation.

The laboratory flame penetration test method used by ARL and later refined by ORNL utilized an oxyacetylene torch to simulate the flame from burning propellant. That test, described in Section 5.1, was the primary method used to evaluate inorganic fiber-based fabrics. The temperatures in that test mimic the temperatures of burning propellant quite well. Cost effective inorganic fabrics, such as silica, cannot withstand the torch flame temperatures very long, however they do not have to as propellant is designed to burn rapidly and burns itself out within seconds.

Several different types of inorganic fabrics were evaluated by ORNL using the oxyacetylene flame test, including silica, basalt and other ceramic fabrics. This testing confirmed that silica fabric performed relatively well in the oxyacetylene flame and met the performance requirement. One layer of silica fabric at a weight of 610 g/m^2 could typically withstand the flame for 4 to 5 seconds before a 100°C increase above ambient temperature was reached. By comparison, a Basalt fabric was tested at weights of 719 g/m^2 and 1061 g/m^2 and the oxyacetylene flame appeared to melt the basalt fabric in about half the time for comparable weight silica fabric.

The silica fabric selected for the application is an amorphous silica fiber with ≥ 94% pure silica, a nominal 9-micron fiber diameter, and an areal weight of 610 g/m^2. The 9 micron diameter is significantly larger than the respirable size range of <3.5 micron. The continuous use temperature of these silica fabrics is typically given as 990°C. Abrasion resistance and handling can be improved by applying a light (≤ 5% by weight) polymeric coating to the silica fabric.

2.3 INORGANIC FIBER-BASED INSULATION

The low thermal conductivity of the insulating mat provides high temperature insulation that resists temperature rise behind the blanket, in addition to providing a significant degree of flame penetration resistance. ARL selected an insulation composed of refractory ceramic fibers (RCF) for their sub-scale prototype fire blankets in their development program. ORNL considered these materials, but they were thought to raise unsatisfactory health concerns for the FBB application. MSDS warnings of "Potential Cancer Hazard by Inhalation" and "some of these studies have found that RCF is a potential carcinogen" appear for RCF materials. The blanket manufacturing process involves humans stitching layers of materials on industrial sewing machines, and RCF insulations are highly undesirable in this manufacturing environment.

Several classes of insulating materials were evaluated in the flame penetration test described in Section 5.1. These include silica mat, RCF fibers, ceramic paper, ceramic blanket, and silica aerogel. RCF insulation test results were found to be comparable to silica mat when compared on an equal weight basis for time to 100°C above ambient. Ceramic papers and blankets containing fibers less problematic than RCF were evaluated, but they typically did not perform as well as silica mat in the flame penetration test. Silica aerogel performed exceedingly well in flame penetration tests and, for the same thickness, performed better than silica mat. However, silica aerogel is a relatively new commercial product, so its price is currently prohibitive for this application.

The insulation selected for the prototype FBB is a silica mat made with the same type of fibers as in the silica fabric chosen for the prototype. These amorphous silica fibers have a silica content of ≥94% and a nominal 9-micron fiber diameter that give the insulation the same *continuous* use temperature as the silica fabric of about 990°C. The material has a nominal shot content (residual non-fibrous particles remaining from fiber production process) of zero. The thermal conductivity at a mean temperature 200ºC is less than 0.071 W/m-ºK. During flame penetration tests it was found that this type of insulation could be subjected to the oxyacetylene torch for 9 to 11 seconds before the temperature behind the insulation rose to 100°C above ambient.

The insulation mat fibers are mechanically interlocked by either needle-punching or a similar process. Dust or small fibers from the insulation that might be thrown into the air by the reciprocating needle of a sewing machine should therefore be minimized The density of the needled mat is 0.12 to 0.14 g/cm^3 and the thickness is nominally 6.35 mm, resulting in an areal weight of 780 to 915 g/m^2.

An added advantage of the needled silica mat insulation is its durability. The FBB must withstand bending, folding, and other rough handling during its deployment and installation. This material holds up better to crushing forces than the more brittle ceramic fiber insulations produced for static applications, such as lining furnaces. The quilting or tufting should do a better job holding this more robust insulation in place than the less durable insulations evaluated.

2.4 COVER MATERIAL

The cover material refers to an outer layer whose purpose is to protect the inner plies of the FBB from the environment and normal “wear-and-tear” handling that might be encountered during deployment. The Kevlar fabric is susceptible to degradation from prolonged exposures to light and moisture. Although an extremely tough material, Kevlar can also be frayed and abraded. The silica fabric and mat insulation are brittle materials whose protection is largely dependant upon the integrity of the outer Kevlar plies. Both Kevlar and silica materials are relatively expensive and keeping them dry, clean and intact will preserve their service life.

During the ARL FBB development phase, the baseline cover material was a Cordura nylon fabric. Initial tests showed that the Cordura fabric burned and could potentially spread flames across and underneath the FBB. Preference was therefore given to identifying an alternative cover material with improved fire resistance.

For the FBB application, expectations are that the cover material (and Kevlar layer beneath) will be penetrated locally by a high heat source, and that the underlying blanket layers will be the primary protection against these threats. Improved fire resistance for the cover material therefore means reducing the potential for ignition from an adjacent heat source, limiting the flame spread beyond the source of the ignition, and that the cover is self-extinguishing when the flame source is removed.

In addition to fire resistance, the cover material must also be lightweight, water-proof, durable, tear resistant, puncture proof, flexible (at subfreezing temperatures), UV resistant, rot proof, colorable (for camouflage purposes), compatible with the stitching and/or heat sealing techniques (for joining) of the FBB manufacturing method, and be low cost. It also reasonable to expect that, in the future, the coating may also need to be Infrared (IR) reflective in this Army application.

Preliminary research suggests that a coated fabric combination may be the best choice for the cover material. Candidate coating materials under consideration are polyvinyl chloride (PVC), chlorosulfonated polyethylene rubber (Hypalon), silicone rubber and a fluoropolymer (Teflon), all of which have demonstrated good fire resistance in commercial applications. Candidate fabrics (or substrates) are woven from polyester, nylon, fiberglass, and aramid (Nomex and Kevlar) fibers.

It should be noted that although polyester and nylon fabrics themselves have poor fire resistance, coupled with the right level and type of coating, these can be made reasonably fire retardant so that they don’t easily ignite, propagate flames and are self extinguishing. Polyester and nylon have the advantages of being lightweight, tear resistant, durable and relatively inexpensive. Polyester has an added benefit in that it is mildew resistant, and has better UV resistance and dimensional stability than nylon (whose fibers can swell in length in settings with high humidity and shorten in dry environments).

Fiberglass fabric is inherently fire resistant, but is not as durable. It can be damaged when repeatedly flexed (creased and folded) and abraded (scored) by sharp objects. Kevlar and Nomex have good fire resistance and are tough and durable, but their higher costs make their use more prohibitive.

A PVC coated polyester fabric formulated for flame retardance and to be self extinguishing was chosen to offer the best combination of fire resistance and durability at an affordable price for the FBB prototypes. A requirement is that the cover material conform to specifications Mil-C-43006G and A-A-55308 for laminated or coated cloth intended for use in the manufacture of protective covers and tarpaulins, which specify a 5 second (maximum) after flame time (time that the specimen continues to burn after the ignition source is removed) and 11.4-cm maximum char length when tested per National Fire Protection Agency standard NFPA 701 (small scale test).

Expectations are that the FBB will be dragged across the ground and pulled over the loaded platform during installation. The pallet contents include wooden boxes with many sharp, splintered edges, and protruding nails and wires. It is also expected that soldiers will walk and jump on top of the FBB during its installation, including after it has been installed over the platform. For these reasons, the 576 to 610 g/m^2 areal weight (described as Type I, or "heavy duty", by Mil-C-43006G and A-A-55308) was selected for the cover material. Although the higher areal weight contributes more to the overall weight of the blanket, it is also the more durable product and should help extend the service life of the FBB in the field.

2. 5 FASTENERS

A system of fasteners is required to secure the individual FBB blanket sections, or modules, to one another along all of the overlapping edges across the top and down the side faces of the platform. These fasteners serve multiple functions. They first act as "location points" along the long seams to guide personnel in the correct positioning and assembly of the blanket over the platform. They also ensure that no gaps develop between the modules during long term storage out in the open and under high wind conditions. Finally, the fasteners provide a convenient method to open and then re-assemble the blanket properly if it should become necessary to retrieve a portion of the platform's stowage during operation

Two options for connecting the FBB modules together include 1) spring clamp buckles and straps, and/or 2) spring clamp buckles and straps in combination with Velcro. The U. S. Army has had good experience with spring clamp buckles in other, similar, applications because they are rugged and easy to use. Velcro would ensure a closed seal along the edges in between the buckle fasteners, but its long term performance under field conditions (particularly if it gets loaded with dirt) is an unknown. All strap and Velcro materials selected for the FBB shall be manufactured from materials that are fire resistant, or which have been treated to be flame retardant.

A separate system of fasteners is also needed to secure the assembled FBB to the metal frames of the platforms. Plans are that these fasteners shall consist of holes with metal grommets equally spaced around the bottom edges of the FBB modules. This approach permits Army personnel to anchor the body modules to various platform frame designs as they best see fit, by lacing cord through the grommets and then tying the cord to the frames at the appropriate attachment points.

3. DESIGN

To meet all requirements, the fire blocking blanket design consists of individual modules that may be assembled in the field, and are sized to be compatible with three of the pallet platforms typically employed by the U. S. military (CROP, 463L and M1), in addition to meeting the U. S. Army's personnel weight lifting restrictions. The modular design of the fire blocking blanket allows for the FBB sections to be stored either individually or as part of a set, transported, and then assembled over the platform in the field of operation by Army personnel.

Figure 4 is a schematic showing the basic shape and features of the FBB modules. They consist of a rectangular "body" module which is laid over the top of the platform and hangs down over the sides. In this concept, coverage is achieved by placing body modules adjacent to one another down the length of the platform. The number of body modules required depends on their width, and the length of the platform. The end modules are placed over the ends of the platform. Two end modules are required for all platform designs.

The "joint" or intersection between individual modules consists of a slight overlapping of one module's edge over that of its neighbor. The intent of the overlapping edges is to minimize the possibility of "gaps" between adjacent module edges that might allow hot fragments to penetrate between the modules and reach the contents beneath.

Part of the design process included establishing the body module's width, and the end module flap width. These parameters are interconnected and control (1) the number of body modules required to provide coverage down the length of the platforms, (2) the amount of material overlap at the joints, and (3) the weight of the individual modules. An additional factor is that although the M1 and CROP platform lengths are reasonably equivalent (5.6 m), the length of the 463L platform is much shorter (2.7 m). Dimensioning the body module width and end module flap width to provide effective coverage for the M1 and CROP platform might not be as efficient a choice for the 463L, and vice versa.

For example, too narrow a body module width means that more body modules are required to cover the platform, increasing assembly time. A wider body module means fewer pieces to assemble, but each section is heavier. Too narrow an overlap width at the FBB joints increases the possibility of "gapping" and that hot debris can penetrate between to the contents beneath. Too wide an overlap increases individual module weight, as well as the expense of the excess material needed to manufacture the modules.

An iterative process was therefore conducted to determine the optimum body module width and end module flap width combination that would work best with ***both*** the long M1/CROP platform envelope and the shorter 463L platform envelope. Criteria for a successful design were defined as a achieving a minimum weight for the individual modules, while also minimizing the number of pieces (body modules) required for assembly. Another desirable feature was maintaining a minimum of 15.2-cm overlap at all body and end module joints.

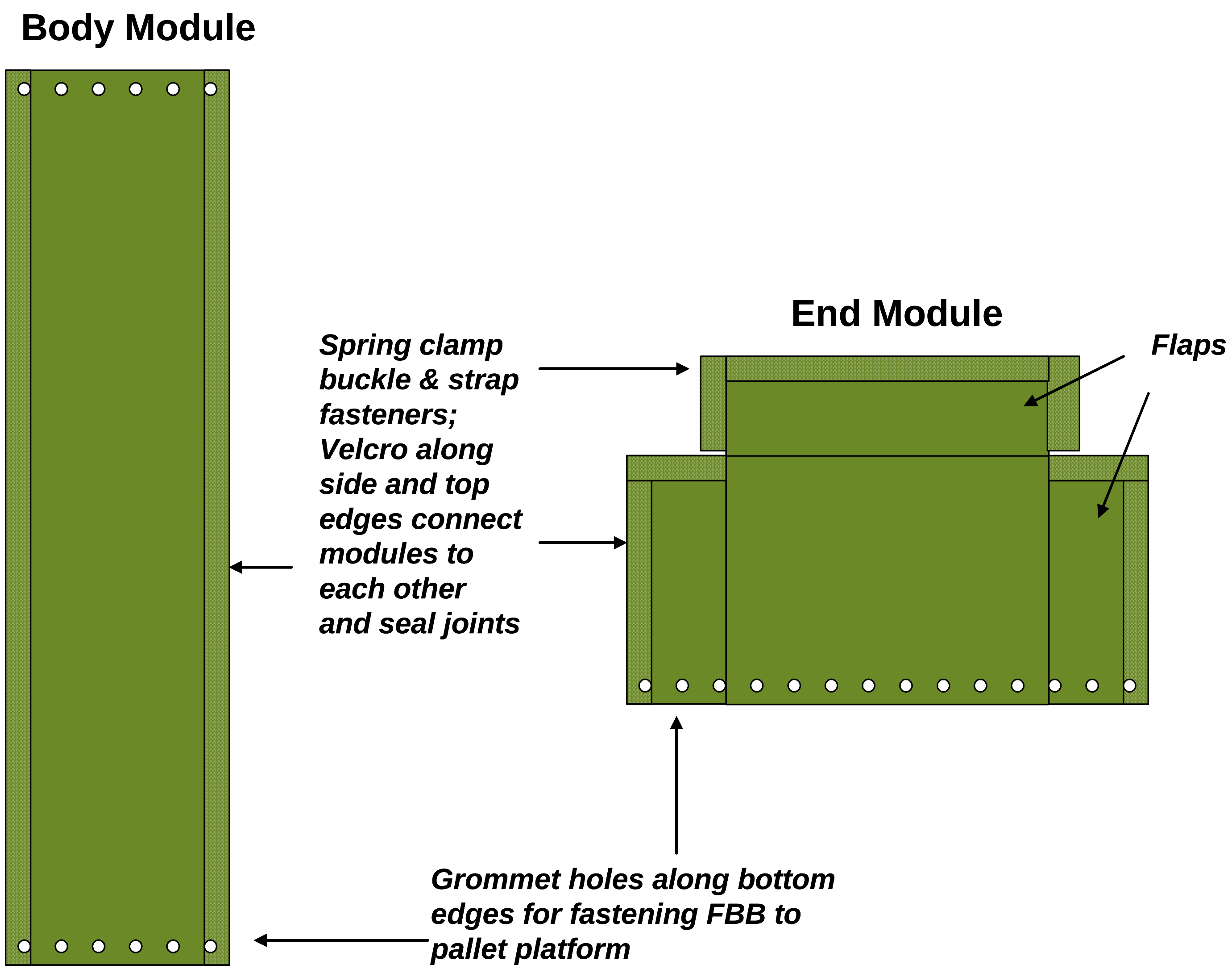


Figure 4. Fire blocking blanket modules

Results of this iteration showed that using a combination of a body module width of 168-cm and an end module flap width of 68.6-cm provided the lowest weight solution for all three platforms, while maintaining an overlap width at all joints of 15.2-cm.

Lastly, the length of the body module was sized so that its lower edges would hang roughly 15.2-cm below the platform of a fully loaded M1 and CROP platform, the intent being to minimize the prospect of hot fragments shooting between the bottom edge of the FBB and platform, and landing adjacent to the ammunition. This scenario could be catastrophic because the thermal insulating characteristics of the FBB would trap the projectile's heat in this instance, perhaps enabling a fire to propagate.

Gates at the ends of the M1 and CROP platforms make it less probable that fragments will land under the edges of the end modules. The length of the end module was therefore sized to reach only to the platform for a fully loaded platform. For a 463L platform, the body and end module dimensions are conservative and should easily reach below the pallet platform on all four sides.

The fire blocking blanket modular design requires that all body modules be interchangeable with one another when placed on the platform, and that both end modules be interchangeable with one another at either end of the platform. To achieve this objective, it is expected that each body module shall have a "male" and "female" edge to reflect the fastener connector pieces along that edge. The end modules may require dual sets of fasteners comprised of both male and female fastener connectors on each edge to be compatible with either a male or female body module edge.

Figure 5 is a schematic for an assembled fire blocking blanket for the CROP and M1 platform using these dimensions, and consists of three body modules and two end modules. Figure 6 shows the same modules assembled for a 463L platform using just one of the body modules and with the same two end modules. The estimated weights for individual modules and for the assembled FBB are in Table 2.

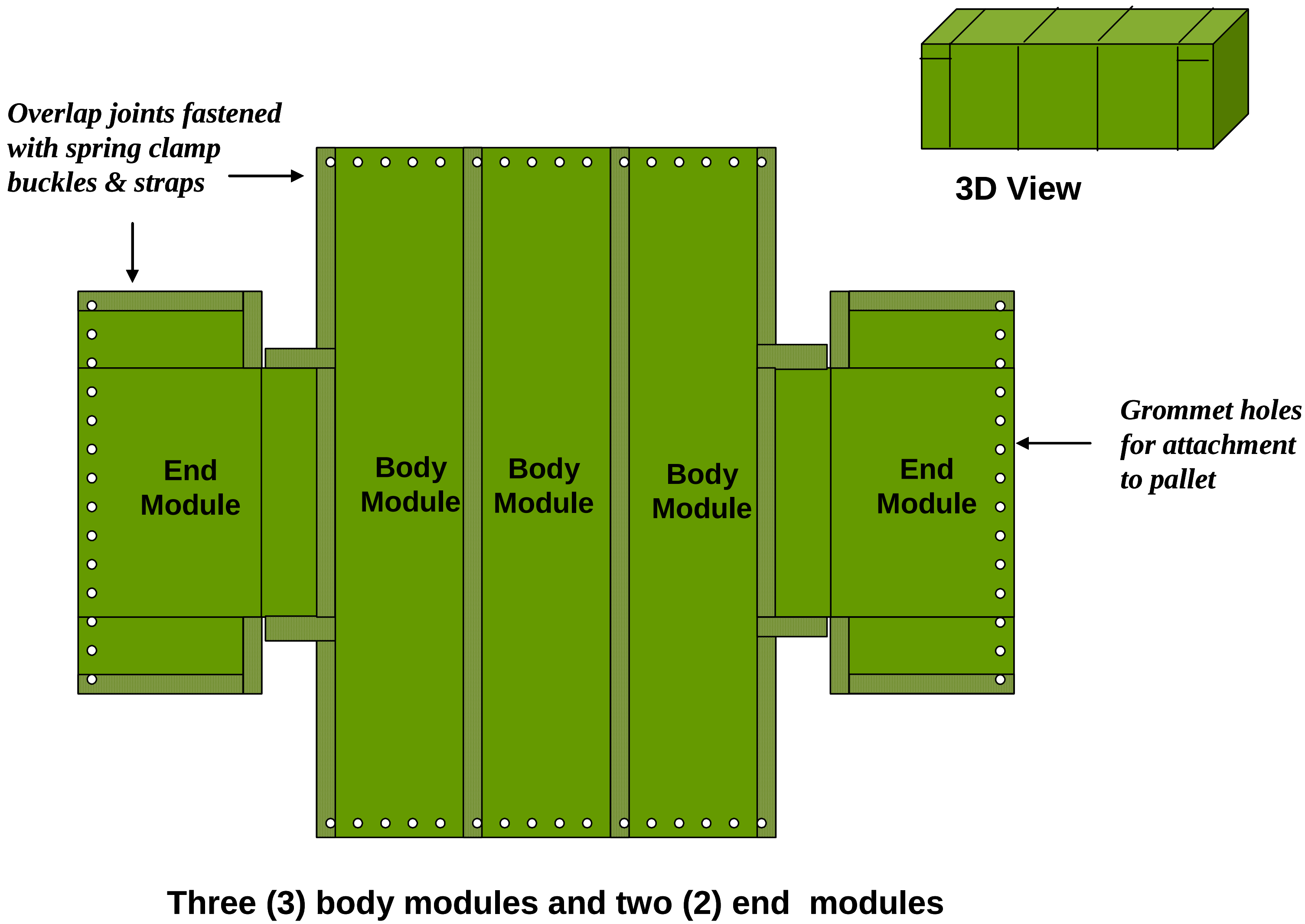


Figure 5. Assembly schematic of fire blocking blanket for M1 or CROP platform.

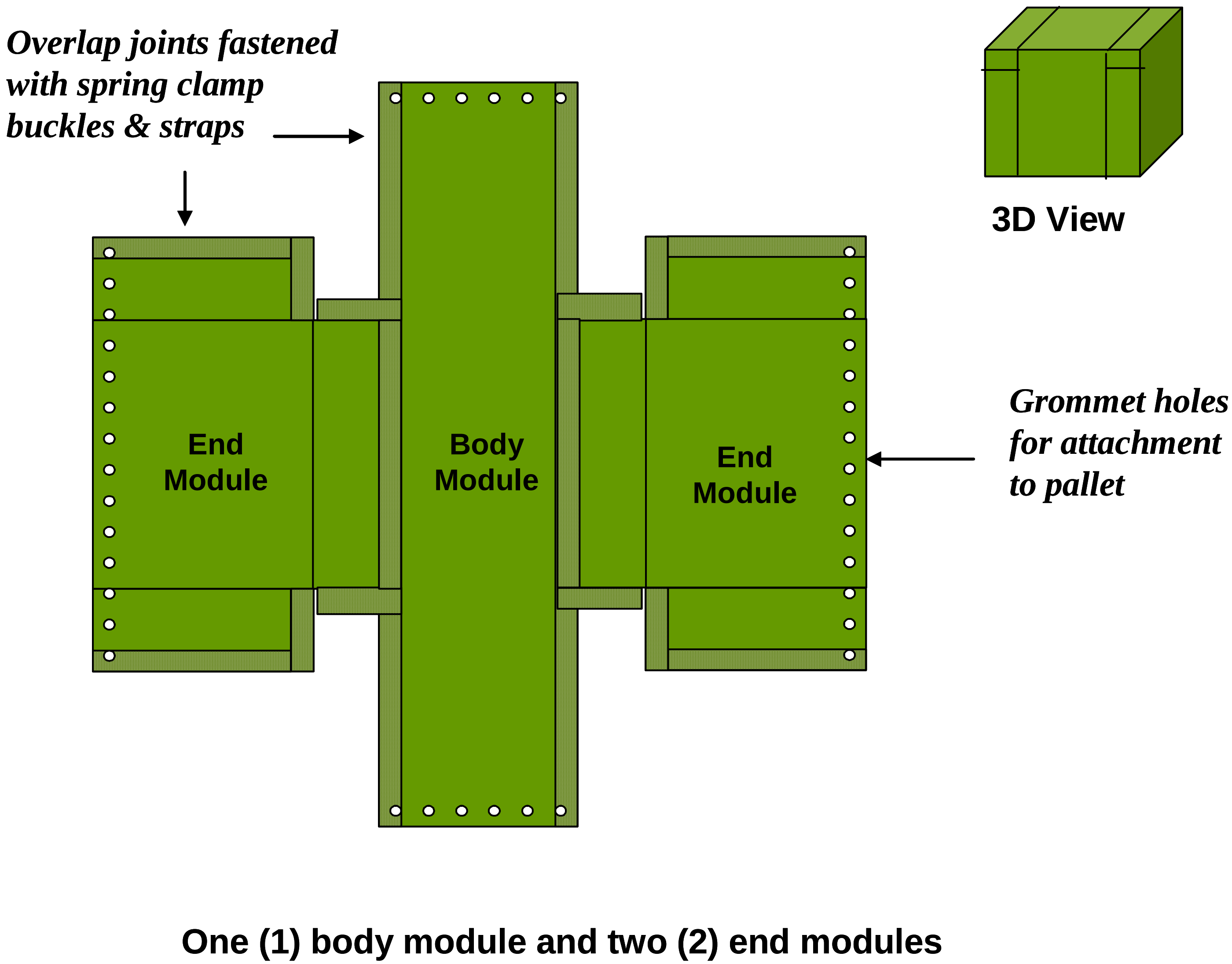


Figure 6. Assembly schematic of fire blocking blanket for 463L platform.

Table 2. Estimated weights for assembled fire blocking blanket (FBB) and modules.

FBB Parameter	M1/CROP	463L
Body module weight (kg)	58	58
End module weight (kg)	48	48
Number of body modules	3	1
Number of end modules	2	2
Total assembled weight of FBB (kg)	270	154

1. Blanket areal weight is estimated to be 0.52 g/cm^2
2. Weight of fasteners not included

4. MANUFACTURE

The production of large numbers of fire blocking blankets for deployment will require the services and expertise of the private sector. A subcontract has therefore been placed by ORNL with Weckworth-Langdon located in Wichita, Kansas. Weckworth-Langdon is a commercial sewing contractor with prior military experience. Scope of work includes the manufacture of two (2) full-size (CROP/M1) prototype fire blocking blankets for the purpose of demonstration and field testing, and the fabrication of up to ten (10) test articles for the purpose of evaluating blanket materials and manufacturing variables that may be used to fabricate the blanket.

Specialized engineering and design support as required to optimize the fire blocking blanket construction for end use are also included as part of the subcontract. Manufacturing aspects that require resolution include:

- Stitching methods and thread selection for assembling the FBB,
- Edge treatments (such as banding, binder tape, stitching, etc) that may be used to finish and "seal" the outer perimeter of the end and body modules,
- Quilting or tufting patterns that may be used to keep fabric layers from sliding/shifting relative to one another in-service,
- Fastener selection and method of incorporation into the finished FBB,
- Methods for splicing and seaming commercially available fabric widths into larger panels,
- Splicing, seaming, and/or heat sealing techniques used to fabricate the outer protective cover, and
- Methods for sealing stitch holes through the protective outer cover to prevent the entry of moisture into the blanket.

The commercial sewing contractor has both the technical expertise and facilities to optimizing the FBB concept into a finished product. The estimated target date for completion of the two full-size FBB prototypes is September 2004.

5. TEST AND EVALUATION

The following sections summarize planned tests and evaluations to characterize the FBB design and materials for acceptability to protect stored munitions during field operations.

5.1 LABORATORY FLAME PENETRATION

A test utilizing an oxyacetylene torch was used to measure the flame resistance of fire blocking materials. This test was initially devised by the ARL(1,2) and modified by ORNL to improve the reproducibility of test conditions. The test methodology shall be briefly described here.

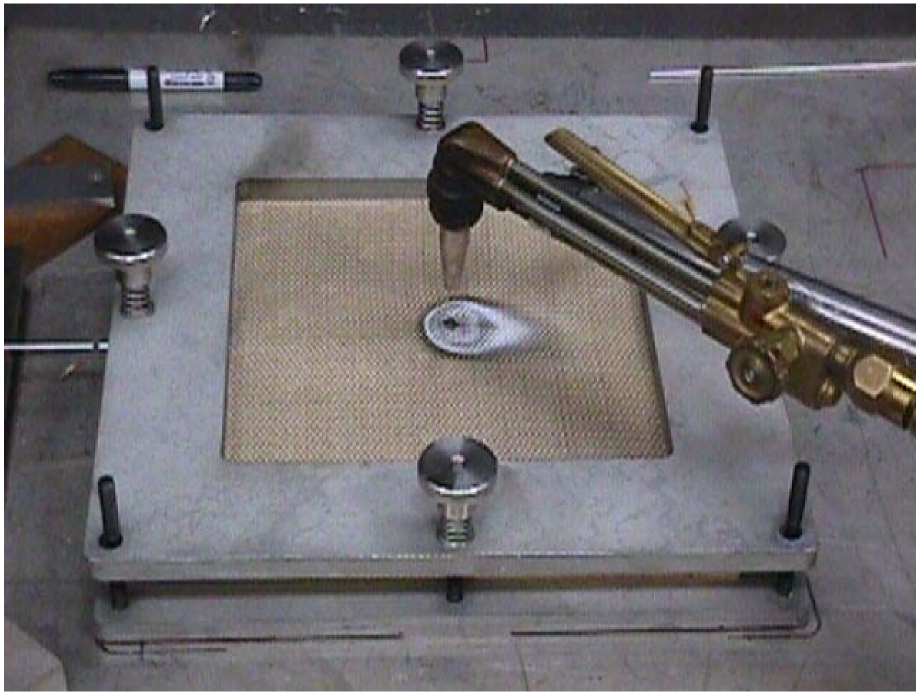
Figure 7 shows the test configuration, equipment and the size 2 cutting tip of the oxyacetylene torch (Oxweld torch with 1502-2 cutting tip and central oxygen flow off) used in these tests. The specimen to be tested was clamped into a metal fixture with a 22.8-cm square aperture. The torch was fixtured so that when lit, could be swung to the center of the specimen so that the tip of the flame inner cone was 19-mm above the test specimen. Gas pressure was set at 276 kPa for oxygen and 34 kPa for acetylene. A flowmeter on each gas line controls the flow rate: 40 L per hr for oxygen and 28 L per hr for acetylene. These conditions produced a reducing flame with a low gas flow. The maximum flame temperature found at the tip of the inner cone is estimated to be over 3000ºC(3,4).

Instrumentation is provided by a K-type thermocouple with a 3.2-mm diameter probe set under all the layers of the specimen. The fixturing along with careful test operation allows the cutting tip to be placed reproducibly over the tip of the thermocouple. Temperature versus time was recorded for the thermocouple and the time to 100ºC and 500ºC was recorded for each material specimen tested.

5.2 SUBSCALE BALLISTIC AND FIRE PROTECTION

Experiments shall be conducted to verify that the FBB materials and methods of construction meet the established ballistic and fire protection. The subscale test article is a nominal 61-cm x 61-cm square, made with the same materials and stacking sequence as for the fire blocking blanket prototype (Figure 3). Triplicate experiments of the FBB shall be tested under each of the following ballistic and flame conditions.

For fragment impact, the FBB test articles shall be secured in an aluminum frame, exposing a 305-mm x 305-mm area of the blanket to fragment impact by a 454 g fragment with an impact velocity of 60 m/s. The fragment shall be a rectangular, mild steel, solid piece with sharpened edges, and shall be launched using a black powder launch system(1,2). The success criteria employed is that there shall be no complete penetration by the fragment through the innermost layer of the ballistic (Kevlar) fabric.



a) Torch positioned over test specimen

b) Cutting tip

c) Welding equipment (torch, gas bottles with flow meter, laboratory hood)

Figure 7. Oxyacetylene torch testing apparatus.

Flame testing shall be conducted with one of the impacted test articles and one unused test article held adjacent and at right angles to each other. The flame source shall be 4.5 kg of bulk propellant and wood piled over the propellant, and two thermocouples per blanket section shall record the heat flux at the rear surfaces of the two sections during the burn. A successful test shall be defined as a temperature increase of no more than 100°C above ambient.

5.3 FIELD FIRE TEST

Experiments shall be conducted at full scale to verify the performance of one of the assembled FBB prototypes. The objective of the field fire test is to provide a full-scale proof test and demonstration of the protection afforded a fully loaded CROP when exposed to fire fueled by propellant and wood.

A CROP shall be loaded with wooden boxes (simulating ammunition boxes) to form the desired load profile, and then covered with the FBB. No live ammunition or other energetic materials will be loaded on the platform for these tests. Various areas of the CROP shall then be exposed to fire according to the matrix provided in Table 3.

Table 3. Field fire test matrix.

CROP Location	Fuel Pile	Number of Tests
Top	4.5 kg bulk propellant	1
Side	4.5 kg bulk propellant	1
Top	4.5 kg bulk propellant & wood	1
Side	4.5 kg bulk propellant & wood	1
Side/partially beneath platform deck	4.5 kg bulk propellant & wood	1

Fire tests shall be conducted using either bulk propellant or bulk propellant mixed with wood as the fuel source. Wood is used in munition pallets and containers, so it is reasonable to expect that in an event in which a platform of munitions is activated, burning wood will be thrown onto fire blankets covering adjacent platforms of munitions. The wood bonfire provides a lower temperature but longer duration threat than the propellant, which typically has a much shorter duration burn.

Tests shall be conducted on top of the CROP and adjacent to its sides. For FBB side evaluations, the fuel pile shall be positioned adjacent to the section of the CROP under test and ignited. For experiments evaluating the top of the FBB, the fuel pile (propellant, wood) will be laid on top. In one test the fuel source shall be positioned partially beneath the deck of the platform. This is done to simulate burning debris that lands beneath the platform and produces heat that rises up through the holes in the CROP floor. This will help determine whether the blanket needs to extend to the ground to stop fuel sources from getting underneath the CROP.

Following ignition of the fuel pile, thermocouples shall record the temperatures in the fire zone at the front and rear surfaces of the blanket. The success criteria applied shall be a temperature increase of no more than 100°C above ambient. During testing, results shall also be documented using video and still photographs.

5.4 DURABILITY AND OPERATIONS TESTING

Operational testing shall evaluate the ease of FBB deployment on loaded platforms (CROP, 463L and M1) and the ease of removal and containment of the FBB. Blanket deployment on a CROP with a maximum height load as well as on a shorter load will be evaluated. A measure of the ease of installation shall be the time required to complete the operation by a specified number of soldiers. Then installation time by two soldiers can be compared to the lesser time required by greater numbers of soldiers. The physical properties of the blanket (weight and size) shall also be confirmed.

Installation involves interlocking the individual blanket modules and securing the FBB to the load platform. Testing shall evaluate the ease with which the fasteners (spring clamp buckles and straps and possibly Velcro) are used to secure the body modules to one another and the end modules. The operation to secure the FBB to the platform using cord laced through grommets near the lower edge of the FBB and secured to the platform shall also be evaluated. Installation in difficult conditions, such as by soldiers suited up in rad gear and operating in extremes of temperature shall also be assessed.

Durability testing shall evaluate the ability of the FBB to withstand rough treatment expected in operational use by the Army in a theater of operations. During installation over the loaded platform, the FBB shall be forced against and over broken or cut wires and cut steel banding and wooden boxes with many sharp, splintered edges and protruding nails. Soldiers are expected to walk and jump on the top of the FBB during and after installation. These same types of rough treatment that can be expected to one degree or another in the field shall be simulated during durability tests. Following each of these types of rough treatment, the condition of the blanket cover and internal layers shall be recorded and evaluated. Potential damage includes lacerations or punctures in the protective cover; damage to the Kevlar layers caused by sharp objects if they are able to penetrate the protective cover; separation of the more brittle ceramic layers inside the blanket so as to break the continuity of the fire protective layers; crushing of the ceramic insulation layer in the center of the FBB; and degradation of the fasteners, stitching or quilting/tufting.

6. SUMMARY

Munitions stored in the open are vulnerable to a multitude of external threats that can lead to their detonation. Stacks of munitions stored in close proximity to one another are particularly vulnerable in that the deflagration of one stack may promote the deflagration or detonation of one or more of its neighbors. A fire blocking blanket (FBB) is therefore being developed that can be placed over storage platforms containing stacked ammunition, and that serves as a barricade to prevent penetration of hot fragments, flame and low velocity projectiles from reaching and detonating the contents beneath.

An FBB design was developed that consists of individual modules that may be assembled in the field, and are sized to be compatible with three of the pallet platforms typically employed by the U. S. military (CROP, 463L and M1), in addition to meeting the U. S. Army's personnel weight lifting restrictions. Materials of construction include Kevlar fabric for ballistic protection, silica fabric and mat insulation layers to serve as a thermal barrier, and a protective outer cover consisting of PVC-coated polyester fabric.

A subcontract was placed with a commercial sewing contractor to manufacture two full-size prototype fire blocking blankets for the purpose of demonstration and field testing, and up to ten subscale test articles for the purpose of evaluating blanket materials and manufacturing variables that may be used to fabricate the blanket. Specialized engineering and design support as required to optimize the FBB construction for end use are also included as part of the subcontract.

Tests and evaluations are planned for later this year to characterize the FBB design and materials for acceptability to protect stored munitions during field operations. Experiments shall be conducted with the subscale test articles to verify that the FBB materials and methods of construction meet the established ballistic and fire protection requirements. A full-scale proof test and demonstration of the protection afforded a loaded CROP when exposed to fire and fragment impact shall be conducted with one of the FBB prototypes. U. S. Army field tests to evaluate FBB assembly, handling and durability characteristics shall be conducted with the second prototype.

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