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Deployment Efficiency and Barrier Effectiveness Testing of a Temporary Anti-Personnel (TAP) Barrier System

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Abstract

This report documents tests conducted by Sandia National Laboratories (SNL) on behalf of the U.S. Department of State to evaluate a temporary anti-personnel (TAP) barrier system developed by Mitigation Technologies. For this, the SNL Denial and Structural Assessment department developed a test protocol for the evaluation of the TAP barrier system on the basis of deployment efficiency and barrier effectiveness against a riotous/mob attack threat. The test protocol was then executed by SNL personnel and the results of the testing are documented.

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NOMENCLATURE

ASTM	American Society for Testing Materials
BF	building fabric
CNM	Central New Mexico Community College
dB	decibel
DOE	Department of Energy
DS/RD	U.S. Department of State, Research and Development Branch
EP	external perimeter
FE	forced entry
ft	foot or feet
in	inch(es)
LE	law enforcement
MB	marine perimeter barriers
MFES	manual forced entry standard
PBAS	Physical Barriers Attack Standard
SC	security containers
SNL	Sandia National Laboratories
TAP	temporary anti-personnel
TSWG	Technical Support Working Group

EXECUTIVE SUMMARY

In support of the U.S. Department of State, Research and Development Branch (DS/RD), Sandia National Laboratories (SNL) Access Delay and Structural Assessment Organization conducted a series of tests designed to evaluate a prototype Temporary Anti-Personnel (TAP) barrier system on the basis of deployment efficiency and barrier effectiveness when exposed to riot/mob attack scenarios.

The principal study objectives were to develop a customized test protocol for the evaluation of the TAP barrier system deployment efficiency and barrier effectiveness during simulated riot/mob attack tests and to exercise the protocol through a series of tests.

Barrier segments were provided to SNL for testing. Testing was conducted in two separate operations, one to measure deployment efficiency, which occurred at Central New Mexico Community College (CNM) campus, and one to measure barrier effectiveness which occurred at SNL Albuquerque Site 9920.

Deployment Efficiency Testing and Results

Teams of four personnel were used during the deployment efficiency testing. Test setup, procedures, execution, and results are found in Section 4. Table 1 shows the average speed for each deployment evaluation test and the range of speeds measured at each upright completion. Note that the average speed is dependent on the deployment layout and the experience of the team. The range of speeds is indicative of the difficulty of deployment. Generally, the deployment teams would struggle at a specific barrier while the rest went up much more readily. This was especially true during deployment over the stair sections. It is also important to note that the speed significantly increases when deploying a section that does not require a base.

Table 1 Summary of test results from the deployment efficiency evaluation

Test #	# of Barriers	Maneuvers/ Setup	Experience	Time (min:sec)	Average Speed ft/min	Speed Range ft/min
1	7 uprights, 6 bases, 3 steps, 2 hinges	30ft concrete, stairs, 90-degree turn, incline	Novice	51:17	0.51	0.1-1.6
2	15 uprights, 15 bases, 1 hinge	70ft, grass, dips/hills, 90-degree turn	Novice	58:01	0.95	0.3-2.5
3	7 uprights, 6 bases, 3 steps, 2 hinges	Same as test 1 (different team)	Experienced	24:00	1.5	0.5-3.3
4	15 uprights, 15 bases, 1 hinge	Same as test 2 (different team)	Experienced	36:14	1.8	0.8-3.8
5	13 uprights and bases	50ft, grass, flat surface, straight setup	Experienced	26:20	1.74	0.8-3.2
6	13 uprights and bases	50ft, concrete, flat surface, straight setup	Experienced	23:12	1.92	1.2-3.9

Based on the results of the deployment efficiency evaluation it was found that the deployment speed for an experienced team (those who have had prior hands-on experience with the TAP barrier system) more than doubled after the team had gained experience from a previous deployment test. Based on this result, it is believed that hands-on training of deployment teams in best practices for setup of the TAP barrier will significantly improve field deployment speed, and result in more consistent/stable barrier setup. The stairs were the most difficult topology to traverse using the TAP barrier system, ranging from 0.14 ft/min for a novice team to 1 ft/min for an experienced team considering deployment speed solely on the stair section of deployment area 1. The novice team had difficulty with the stair section, requiring multiple re-constructions. The primary difficulty is due to the limitations in overall height change with each adapter component. Other results, conclusions, and recommendations are discussed in Section 4.

Barrier Effectiveness Testing and Results

Climbing, breaching, and thermal attack scenarios were conducted in order to determine the barrier effectiveness to riotous threat scenarios. Test setup, procedures, execution, and results are found in Section 5. Table 2 summarizes the attack test results.

Table 2 Summary of attack delay test times. RED indicates successful breach, GREEN indicates unsuccessful breach, and BLUE indicates the test was stopped for safety purposes

Test Number	# Of Attackers	Tools	Attack Technique	Time (minutes)
1 and 2	1	None	Climb: unaided w/base	0.10
3 and 4	2	None	Climb: aided w/base	0.16
5	1	Ladder	Climb: ladder w/base	0.18
6	12	None	Breach: coordinated push w/base	10.75
7 and 8	1	Masonry bricks	Breach: projectile/ masonry	3.93
9	2	Hydraulic jack	Breach: lift w/jack	1.11
10 and 11	1	2”x4” lumber, Steel sign post	Breach: improvised ramming tools	1.95
12	N/A	None	Breach: improvised incendiary	N/A
13	1	Steel sign post	Breach: ram/post-incendiary	0.45
14	1	None	Climb: unaided, no base	0.45
15	2	None	Climb: aided, no base	0.25
16	12	None	Breach: coordinated push, w/out base	0.23
17	1	Crowbar, chisel	Breach: peel mesh/post-incendiary	3.36
18	1	Crowbar, chisel	Breach: peel mesh	3.50
19	1	Crowbar, chisel, Hammer	Breach: separate hinged corner	2.83
20	1	Steel sign post	Climb: defeat spikes	N/A

Analysis of the attack testing results indicates a barrier system that is robust considering its light weight and portability. The testing showed that in the absence of deployed spikes on top of the uprights, the barrier is highly susceptible to climbing attacks. Both single- and two-person attacks readily traversed the barrier. The spikes are likely to significantly deter climbing without available aids. Tests were performed to defeat the spikes and it was shown that the defeat methods tested were relatively slow with undetermined benefit. Attackers with climbing aids (ladders, blocks, etc.) likely still would be able to defeat the barrier, but these tests were not performed due to safety considerations.

Breaching via a coordinated push attack was relatively ineffective when performed on a supported upright, but was highly effective at an unsupported upright location (uprights without bases), which are likely to be present in most TAP barrier deployment layouts. The unsupported upright locations are likely to be the weak points in the TAP barrier system. Adapter components are similarly unsupported and potential weak points. If at all possible the deployment team should avoid adjoining two unsupported straight uprights. Lifting the barrier using a hydraulic jack is believed to be a viable defeat path although testing was stopped for safety slightly prior to completion. The unsupported barrier locations are again the most vulnerable locations to the hydraulic lift attack scenario. Breaching via projectiles and rams are both viable; the steel sign post was the most effective breaching tool, and wood 2 in. x 4 in. was relatively ineffective. The simulated Molotov cocktail thermal attack caused minimal peeling of the upright mesh on the TAP barrier. Other results, conclusions, and recommendations are discussed in Section 5.

1 INTRODUCTION

1.1 Overview

In support of the U.S. Department of State, Research and Development Branch (DS/RD), Sandia National Laboratories (SNL) Access Delay and Structural Assessment Organization conducted a series of tests designed to evaluate a prototype Temporary Anti-Personnel (TAP) barrier system on the basis of deployment efficiency and barrier effectiveness when exposed to riot/mob attack scenarios. Mr. Russell J. Norris and Mr. Keith M. Nelson of DS/RD served as the program lead and engineer respectively. Mr. Ruben Martinez served as the SNL project lead.

The DS/RD, in collaboration with the Technical Support Working Group (TSWG), and Mitigation Technologies developed a new TAP barrier system. The TAP barrier is a rapidly deployable, expedient, man-portable, modular system designed to aid security professionals in crowd control and establishing temporary perimeters and set-backs.

The deployment efficiency tests were performed on November 29th, 2016 by SNL personnel at the Central New Mexico Community College (CNM) campus. Dr. David Allen was responsible for the development of the deployment evaluation test protocol, organization, and test operations. The deployment efficiency evaluation was supported by multiple SNL personnel during setup, testing, and videography; including Ruben Martinez, Steve Highland, Stephen Neidigk, Tom Rice, Terry Hogan, Steve Hill, Ethan Tanner, Zak Wilson, Fred Snoy, Chris Hall, David Guba, Charles Hedrick, and Vince Gasparich.

The barrier effectiveness testing was performed on November 30th, 2016 by SNL at the explosive test facility at Site 9920 operated by SNL's Explosives Research and Development organization. Mr. Charles Hedrick was responsible for the development of the riot/mob attack test protocol, organization, and test operations. Dr. John Rudolphi served as Site 9920 operations engineering representative and lead engineer for the thermal attack testing. The barrier effectiveness testing was supported by multiple SNL personnel during setup, testing, and videography; including Ruben Martinez, David Allen, Steve Highland, Stephen Neidigk, Tom Rice, Terry Hogan, Steve Hill, Ethan Tanner, Zak Wilson, Fred Snoy, Chris Hall, Keith Osenbaugh, Charles Hedrick, Carrie O'Hara, Kevin Jameson, Andrew Thompson, Mark Naro, Mike Huckaby, Derek Farr, and Vince Gasparich.

1.2 Purpose

Prototype TAP barrier components were recently subjected to several laboratory structural load tests [ref 1]. DS/RD wanted to further evaluate the barrier's ease of deployment on varying terrain conditions and to test the barrier effectiveness when subjected to a simulated riot/mob attack. To achieve these goals, DS/RD engaged SNL to develop a customized test protocol and conduct testing of the TAP barrier system against multiple simulated mob attack scenarios.

According to the designers, the TAP barrier system is a modular, lightweight, reconfigurable, reusable, man-portable barrier system intended to deter and delay a violent crowd. Most of the components that comprise the barrier are made of aluminum. Modules interlock with each other to form a continuous barrier that is approximately 9 feet (ft) tall.

1.3 Objectives

The principal objectives of this study were to:

- Develop a customized test protocol for the evaluation of the TAP barrier system deployment efficiency and barrier effectiveness during simulated riot/mob attack tests.
- Perform deployment efficiency tests to measure the ease of deployment over varying topology and conditions. Measure the ease of deployment using appropriate metrics developed in the customized test protocol. Collect feedback for further system improvement.
- Perform simulated riot/mob attack tests to measure barrier effectiveness using the customized test protocol. Measure and document the barrier effectiveness using appropriate metrics developed in the customized test protocol. Collect feedback for further system improvement.

2 FORCED ENTRY LITERATURE REVIEW

A literature search was conducted during August/September 2016 in support of the TAP test protocol. This literature summary reviewed 11 articles and books and consulted with a subject matter expert on the subject of civil unrest, mob actions, riots, and similar events. The majority of the reviewed publications were intended for use by civil authorities and focused on response. [refs 2-8] Instructional topics for use by law enforcement (LE) such as field formations, tools, weapons, and riot-control chemical agents are discussed in great detail. Background information regarding the rioters themselves is less prevalent and mostly serves to characterize riotous groups and provide insight on crowds and situations having potential to escalate into riots. Generally, the information provided on riot behavior is intended to review broad patterns of activity such as assaultive actions directed at LE and widespread property damage. Potential LE countermeasures for these activities are thoroughly discussed.

Some of the literature discovered were test standards related, but not directly applicable, to the evaluation of site perimeter barriers. Other related information was found in field test result summaries of common and novel perimeter barriers. This information helped inform the development of the attack-testing protocol developed for the present series of tests. The applicable standards are summarized in Table 3 and a brief description of the standards is provided in the following section.

Standard Practice for Testing Forced Entry, Ballistic, and Low Impact Resistance of Security Fence Systems, ASTM F2781-15, 1 November 2015

This standard practice defines an approach to evaluate the resistance of a fence system to forced entry, ballistic impact, and low-velocity impact from a small vehicle. The standard defines three threat levels: 1) Low, 2) Medium, and 3) Aggressive. It states the procedures are intended to evaluate the time necessary for vandals and unsophisticated criminals to forcefully penetrate security fence systems using manually operated tools. [ref 2]

Standard Test Method for Timed Evaluation of Forced-Entry-Resistant Systems, ASTM F3038-14, 15 April 2014

According to the scope, this test method is intended primarily for manufacturers to test and rate their windows, doors, modular panels, glazing, louvers, walls, seismic joints, roofs, roof hatches, grilles, and similar products to ensure that all manufactured products meet the necessary requirements for forced-entry protection. Although the test method is intended to simulate a spontaneous mob using readily available hand tools as the primary threat for forced entry, it does not appear to be directly applicable to perimeter site barriers. The standard appears to be largely based on the "Department of State Forced Entry and Ballistic-Resistance of Structural Systems," Revision G, SD-STD-01.01. [ref 3]

Manual Forced Entry Standard (MFES) Version 1.0, Part 1: Requirements, Centre for the Protection of National Infrastructure (CPNI), 1 April 2015

This standard replaces the "Physical Barriers Attack Standard (PBAS)" and is intended for building fabric (BF), external perimeter (EP), security containers (SC), marine perimeter barriers (MB), and other systems requiring forced entry resistance. The standard defines three distinct attackers (Novice, Knowledgeable, and Expert) based on tool sets, experience with the tool set, experience attacking products, knowledge of the product, and physical fitness. It also defines three threat levels (Base, Enhanced, and High) that are aligned with the attacker definitions. All threat levels involve two attackers. For the specific product under evaluation (e.g., EP), a range of resistance time classifications are defined. These times vary from 0 to 20 minutes. [ref 4]

Requirements and testing procedures for the LPCB approval and listing of intruder resistant building components, strongpoints, security enclosures and free-standing barriers, LPS 1175: Issue 7.2, March 2014

This British standard describes tests for classifying the intruder resistance of building components, strongpoints, security enclosures, and free-standing barriers. It does not address the resistance to thermal shock attack, chemical attack, vehicle impact, explosion, or ballistics. There are eight different attack tool sets defined. [ref 5]

Barrier Technology: Perimeter Barrier Penetration Tests, Sandia National Laboratories, SAND78-0241, November 1978

This report summarizes a series of field tests investigating the personnel delay of four perimeter barriers. The barriers consisted of varying arrangements and types of concertina wire. One of the four tests also involved a rocket-propelled ¾-ton pick-up truck. [ref 6]

Barrier Penetration Tests, US Department of Commerce, National Bureau of Standards NBS Technical Note 837, June 1974

This report summarizes a series of field tests performed on varying building wall types and security fences. Results are reported for seven different attacks scenarios on varying types of chain link fence. The fence was seven-ft high and was topped with outriggers supporting three strands of barbed wire. The author reports “The test results indicate that the deterrent influence of electrified fences of the type tested is largely psychological rather than physical. All of the specimens could be penetrated in less than 0.14 minutes (8.4 seconds). [ref 7]

Riot Control Barrier – Concept Development and Feasibility Test, US Army Land Warfare Laboratory, Technical Report No. 74-25, April 1974

This report summarizes the design and field testing of two riot control barriers that were intended to be modular, rapidly deployable, lightweight, fire-resistant, reusable, and able to delay an undetermined individual for 5 to 10 minutes and a determined individual for 3 to 5 minutes. The design of all barrier prototypes consisted of an equilateral triangle cross-section with eight-ft long sides. One barrier prototype consisted of corrugated *steel* panels and the other barrier prototype consisted of corrugated *aluminum* panels. (A third prototype consisted of corrugated steel panels with sharp steel spikes running along the top apex. Because the spikes could inflict permanent body injury this prototype was ruled out by the test conductors and was never tested.) The two base corners and top apex corner for the steel barrier were connected using ¼-inch-diameter threaded rod running through the nested panel flutes. The aluminum barrier utilized wire rope instead of threaded rod. [ref 8]

Table 3 Relevant references pertaining to forced entry standards

ID	Name	Threat Level, or Protection Level, or Tool Sets Employed	Number of Attacker's	Test Durations	Performance or Pass/Fail Criteria Definitions	Relevant Notes
	"Standard Practice for Testing Forced Entry, Ballistic, and Low Impact Resistance of Security Fence Systems," ASTM F2781-15, 1 November 2015 ASTM INTERNATIONAL	Three for forced entry (FE) ▪ Low (L) ▪ Medium (M) ▪ Aggressive (A) Standard identifies 35 tools. Tools include hand, electric and gasoline powered, and thermal. Use of more aggressive tools are reserved for the higher threat levels Two for ballistic ▪ 0.38 Special (158 grain, lead) ▪ 7.62 (M80 ball) One for impact vehicle ▪ 4,000-lb bogie traveling 20 mph	▪ Two ▪ Two ▪ Four	0 to 5 minutes and 0 to 55 minutes	FE = 2-ft x 2-ft opening Ballistic = perforation of witness plate behind test specimen Impact vehicle = static displacement of the barrier and size of opening created, if any	
	"Standard Test Method for Timed Evaluation of Forced-Entry-Resistant Systems," ASTM F3038-14, 15 April 2014 ASTM INTERNATIONAL	A single hand tool set is defined. No powered (electric, hydraulic, gasoline) tools.	▪ Six	Varies from 0 to 60 minutes	Passage of elliptical test block: 400-mm major axis by 225-mm minor axis and 300 mm high	Per the scope of the test method: "This test method is currently designed to simulate a spontaneous mob using readily available hand tools as the primary threat for forced entry."
	"Manual Forced Entry Standard (MFES) Version 1.0, Part 1: Requirements," Centre for the Protection of National Infrastructure (CPNI), April 1st 2015 CPNI Centre for the Protection of National Infrastructure	Three ▪ Base ▪ Enhanced ▪ High	▪ Two ▪ Two ▪ Two	Varies depending on the products application, but ranges from 0 to 20 minutes	Varies depending on the product or system being tested. For EP, criteria is defined as: 1) passage of both attackers completely through the product to the protected side together with their chosen tool kit, or 2) passage of both attackers completely over or under the product to the protected side with their chosen tool kit.	Per the scope of the standard: "The standard applies to manual attacks conducted by pairs of attackers. It does not cover attacks conducted by mobs, nor does it cover the use of ballistics, explosives, and other munitions."

ID	Name	Threat Level, or Protection Level, or Tool Sets Employed	Number of Attacker's	Test Durations	Performance or Pass/Fail Criteria Definitions	Relevant Notes
	"Requirements and testing procedures for the LPCB approval and listing of intruder resistant building components, strongpoints, security enclosures and free-standing barriers," LPS 1175: Issue 7.2, March 2014	Eight tool categories are defined (A,B,C,D,D+, E, F, G). Each category includes a note discussing adversary tactic, skill, desire to remain covert or overt, and motivation	One. substitution allowed	0 to 20 minutes	Passage of elliptical test block: 400-mm major axis by 225-mm minor axis and 300 mm long Note: Scaling over or tunneling under free-standing barriers outside of the standards scope.	
	Barrier Technology: Perimeter Barrier Penetration Tests, Sandia National Laboratories, SAND78-0241, November 1978	Thirteen different types of "breaching" aids were utilized including hand tools, plywood, carpet, and three types of ladders	Scenarios involved 1, 2, or 3 attackers	Test durations ranged from 11 seconds up to 9 minutes 25 seconds. Of the 27 attacks performed: 18 were $\leq$ 1 min 23 were $\leq$ 2 min	Defined as the point at which one attacker made it over/through the barrier	
	"Barrier Penetration Tests," US Department of Commerce, National Bureau of Standards NBS Technical Note 837, June 1974	Basic hand tools and power tools used including 2x4, bolt cutters, linesman pliers, wire ladder, tarpaulin, and cut-off saw	Scenarios involved 1 or 2 attackers	Test durations ranged from ~3 sec. up to ~48 sec. Of the 43 attacks performed: 18 were $\leq$ 1 min 23 were $\leq$ 2 min	Creation of 96-in^2 opening or complete under or overpass of 1 attacker	
	Riot Control Barrier – Concept Development and Feasibility Test, US Army Land Warfare Laboratory, Technical Report No. 74-25, April 1974	None	Scenarios involved 1, 2, or 4 attackers	No times reported	Not explicitly stated, but assumed to be the successful	

3 TEMPORARY ANTI-PERSONNEL (TAP) BARRIER DESCRIPTION

3.1 Design Description

As stated in the TAP Barrier field manual [ref 9] “The TAP Barrier is a rapid-deployment crowd control perimeter fence system:

- With interchangeable components providing maximum configuration flexibility to accommodate a wide variety of topographical and site conditions
- Intended to delay access by hostile crowds to secure facilities and provide embassies and other end users with additional time to protect and defend personnel and real property
- Designed for efficient and compact breakdown to store and transport in 20 ft. conex shipping systems
- Tested to spec BAAA 13-Q-3025
- Proven to be deployed in under 20 seconds per foot.”

Figure 1 through Figure 15 show images of the TAP barrier components that were involved in testing. The solid model renderings were obtained from the *TAP Barrier Field Manual Operations and Maintenance Guide*. [ref 9] The primary components are the base section, upright assembly, adapter, corner hinge, and termination components (male). There were also spikes that were provided and used in one set of tests.

Base Assembly

The base assembly components are designed to support the upright assembly and are shown in Figure 1 through Figure 4. The base assembly uses quick locks at the bottom of the upright to lock the upright into place, and a strut to support the upright from tipping. The full base/upright assembly, called a straight section when assembled, can be seen in Figure 14.

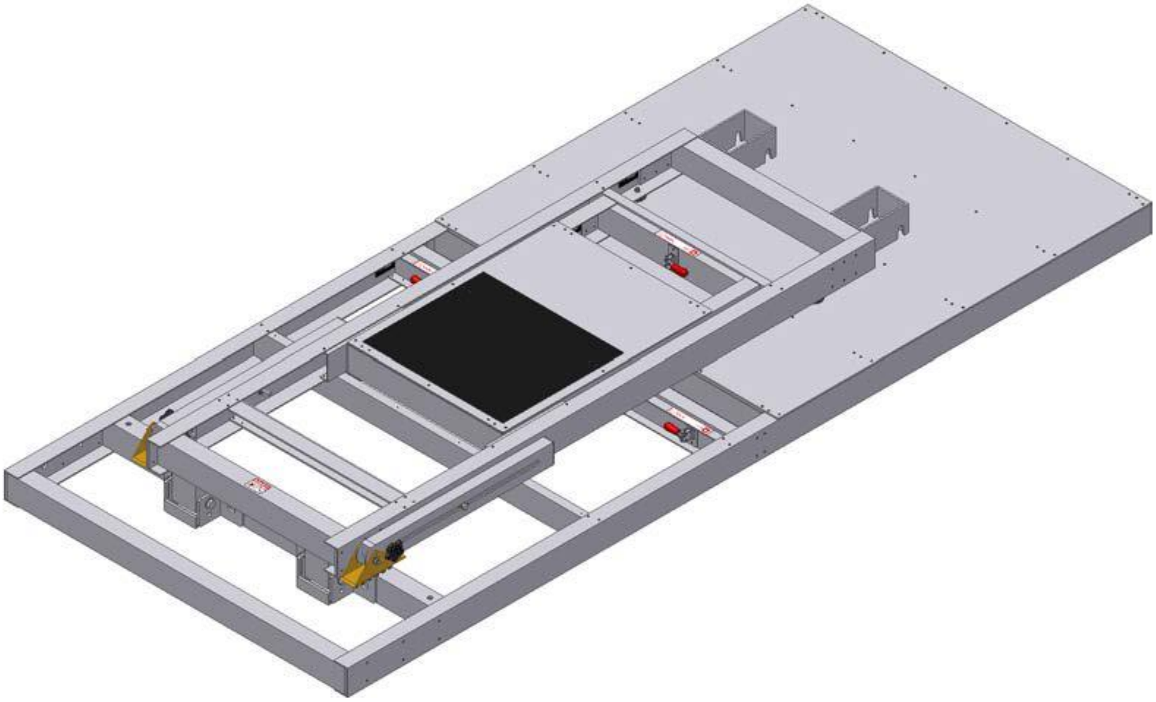


Figure 1 Rendering of base assembly in storage position [ref 9]

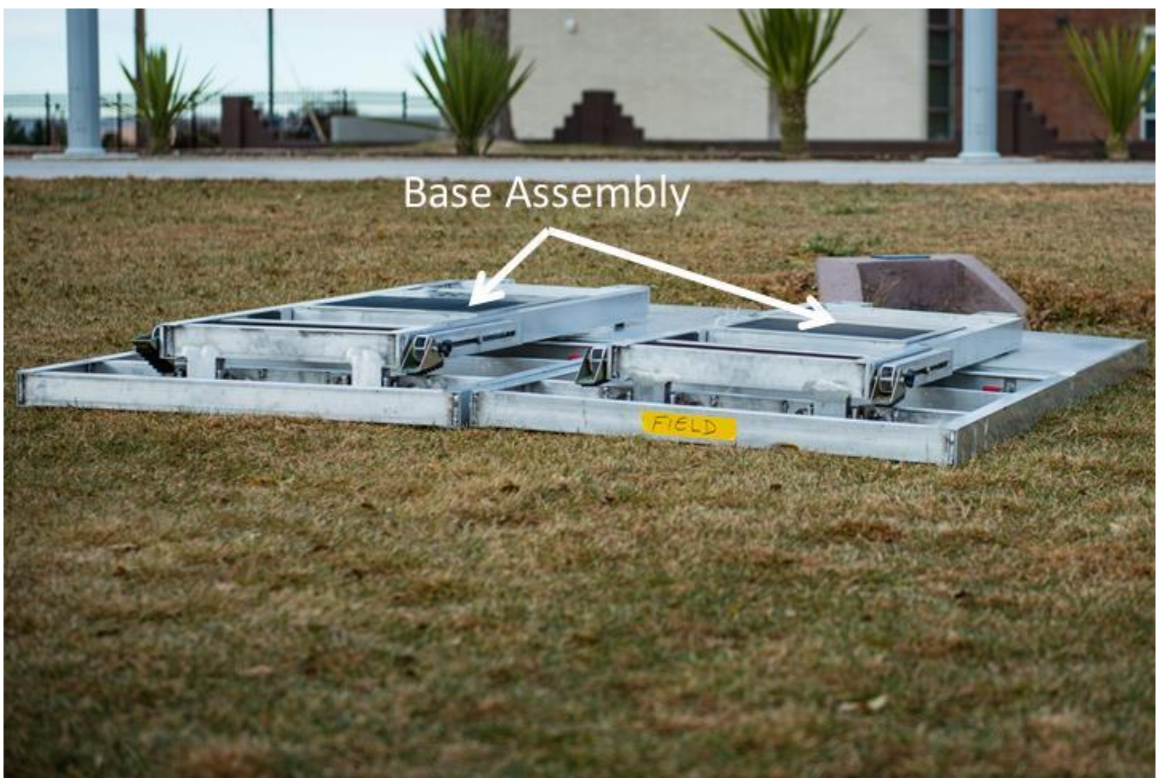


Figure 2 Two base assembly components in storage position that were used for deployment efficiency testing

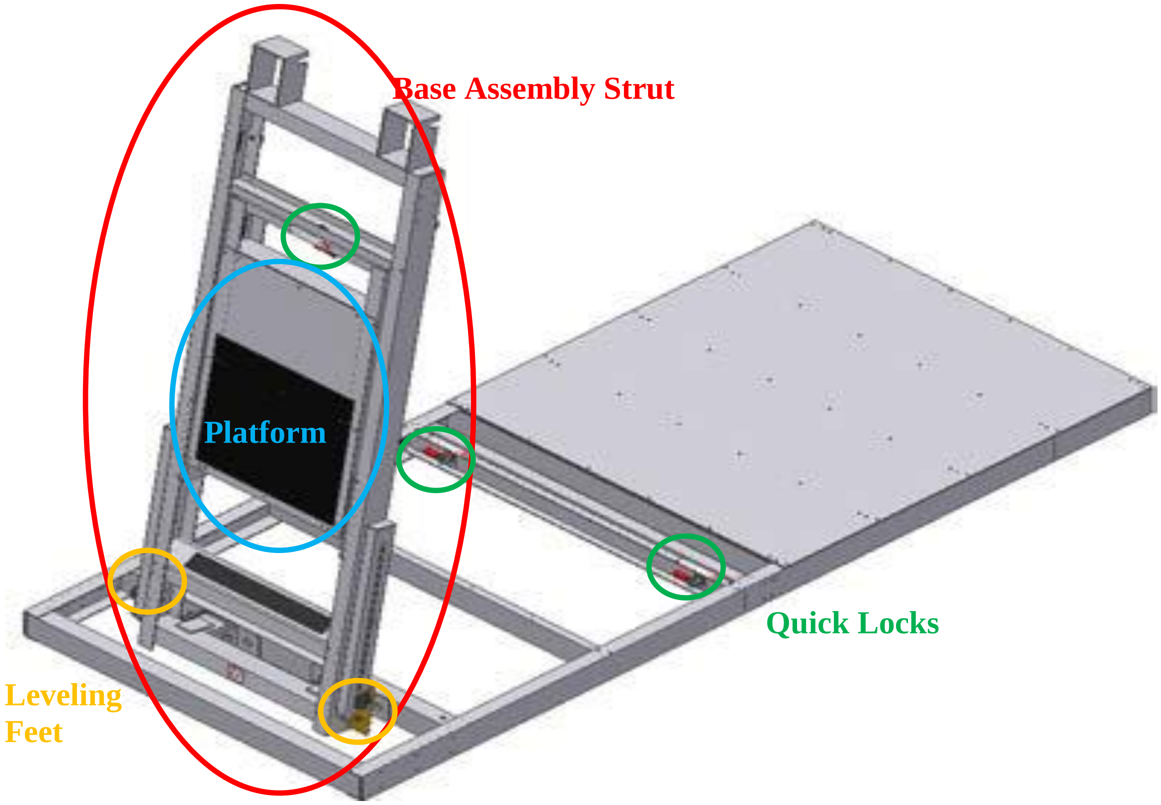


Figure 3 Rendering of base assembly with strut component upright, platform locked [ref 9]


Figure 4 Base assembly in upright position during deployment efficiency testing

Upright

The upright component provides the vertical wall of the TAP barrier and connects to the base assembly. The upright is primarily made of aluminum, with a mesh material on the front that obscures vision and prevents climbing/penetration. Multiple versions of the upright were sent to SNL for testing, each from a different stage of design. The versions were labeled prototype, hybrid, and unlabeled. An example of an upright is shown in Figure 6. The differences were primarily in the overall height of the upright mesh and the mesh material. The unlabeled panel was described as the "production" panel that would be used going forward in the development of the barrier system.

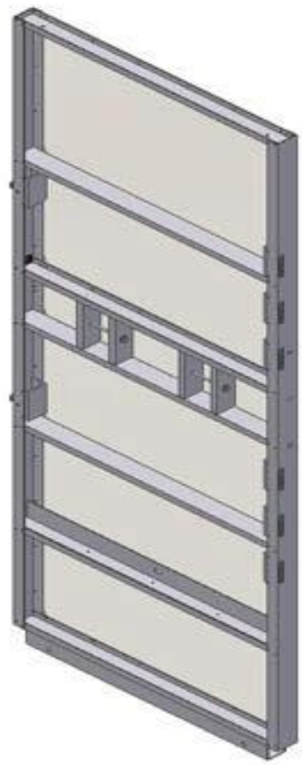


Figure 5 Rendering of upright assembly [ref 9]

Figure 6 Upright assembly in use during deployment efficiency testing

Adapter Component

The adapter component is used to vary the width of a segment, during an elevation change. The maximum height change that can occur when connecting two vertical components together is 8 inches (in.). When connecting two upright assemblies together the possible span is 8 in. vertical over the width of the upright (44 in.) with some flexibility. When a steeper slope or height change must be achieved the deployment team must preemptively adjust the height. This may result in a gap between the ground level and the bottom of the adapter component that is less than 8 in. high.

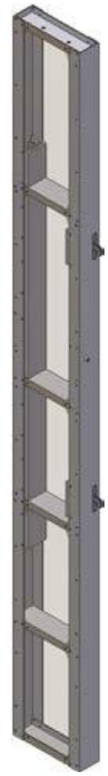


Figure 7 Rendering of adapter component [ref 9]

Figure 8 Adapter in use during deployment efficiency testing

Corner Hinge

The corner hinge component is used to perform a turn that is less than 90 degrees. The hinge components are unsupported by base assemblies, similar to the adapter components. Multiple hinge components can be used in succession with upright and base components in between each hinge to perform wider turns with greater support.

Figure 9 Rendering of corner hinge component [ref 9]

Figure 10 Adapter in use during deployment efficiency testing

Termination Component

The termination component is required to anchor the TAP barrier assembly to an existing structure. Without the termination, the wall will be unsupported at each end. When possible, the termination components are suggested to be anchored to a predetermined location prior to deployment. Mounting the termination components requires installing appropriate length fasteners through the mounting plate and into the support wall. Male and female termination components are used in order to terminate on either side of an upright section.

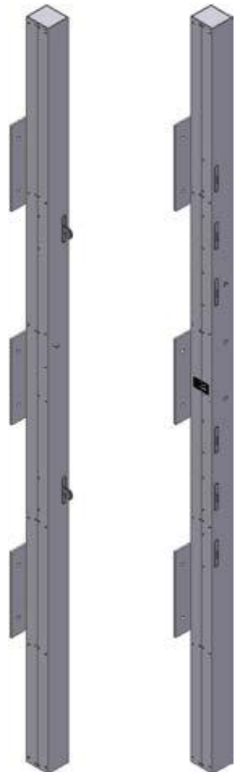


Figure 11 Rendering of male (left) and female (right) termination components [ref 9]

Spikes

The spikes are used to deter potential rioters from climbing over the TAP barrier. For safety purposes, the spikes were not used during the climbing attacks associated with the barrier effectiveness testing. The spikes were used for tests specific to spike defeat. Tests were performed to determine how long it may take to bend the spikes and what tools may be used for such an attack. The spikes are shown in Figure 12 and Figure 13.

Figure 12 Spikes that were available during barrier effectiveness testing (not assembled on upright)

Figure 13 Spikes installed atop upright during barrier effectiveness testing

Straight Section

The base and upright are assembled together to form the primary component of the Tap barrier wall called a straight section. The upright is inserted into the slot within the base, and the platform is raised into position to brace the upright. There are quick locks that are used to securely latch the components together. Another straight section can be attached on either side of a previously deployed straight section.

Figure 14 Rendering of the full base and upright assembly in an assembled position (straight section) [ref 9]

Figure 15 Multiple straight sections assembled during deployment efficiency testing

Tools

The TAP barrier system uses minimal tools. The crowbar tool shown in Figure 16 and Figure 17 is used to level the base components while latching the quick locks. The quick locks are latched using a 5/16 hex wrench as shown in Figure 18.

Figure 16 Crowbar leveling tool [ref 9]

Figure 17 Crowbar leveling tool being used during deployment efficiency testing

Figure 18 Deployment team member latching a quick lock using one of the hex wrench tools provided

3.2 Deployment Process

A thorough description of the deployment process can be found in the *TAP Barrier Field Manual Operation and Maintenance Guide*. [ref 9] The TAP barrier was designed with rapid deployment as a key objective. The components are modular and lightweight. The upright weighs 86.4 pounds (lbs.) and the base section weighs 164.7 lbs. The primary tap barrier component is the straight section which consists of the combined base and upright assemblies. This section is deployed by laying the base section down, raising the platform, and inserting the upright into the slotted section of the base. The platform is then lowered and the quick locks are all locked into place as shown in Figure 19 through Figure 23. The platform is folded down by unlocking the upper quick lock shown in Figure 3. The upright is locked into place by locking the 2 lower quick locks also shown in Figure 3.

Table 4 Table of common maneuvers and the required components and tools for deployment

Maneuvers	Required Components	Required Tools
45-degree turn	2 bases, 2 uprights, 1 hinge	Base tools
Wide 90-degree turn	3 bases, 3 uprights, 2 hinges	Base tools
Compact 90-degree turn	2 bases, 3 uprights, 1 hinge	Base tools
Steps	2 bases, 2 uprights, ~1 adapter/step (depends on step width)	Base tools

Maneuvers	Required Components	Required Tools
Curbs	2 bases, 2 uprights, 1 adapter or another upright (depends on width of curb)	Base tools
Slopes	X uprights, X bases (varies based on slope)	Base tools
End point	X uprights, X bases, 1-2 adapters, 1 termination	Base tools, drill, wall mount hardware
Dirt/grass installation	Uprights, bases, adapters (amount varies)	Base tools, grounding stake

Figure 19 Straight section positioning during deployment efficiency evaluation

Figure 20 Straight section positioning during deployment efficiency evaluation (cont'd.)

Figure 21 Straight section positioning during deployment efficiency evaluation (cont'd.)

Figure 22 Straight section positioning during deployment efficiency evaluation (cont’d.)

Figure 23 Straight section positioning during deployment efficiency evaluation (cont’d.)

Once a straight section is put into place, adjoining straight sections can be connected to the already deployed component following the same process as before with the additional step of latching the uprights of the two straight components together. In order to latch the uprights of two adjacent straight sections, the deployment team must line up the alignment pins as shown in Figure 24 and Figure 25. Once aligned, the quick lock latches must be rotated using the hex wrench to lock the uprights together as shown in Figure 26 and Figure 27.

Figure 24 Alignment pin used for adjoining two adjacent straight sections

Figure 25 Alignment pin used for adjoining two adjacent straight sections (cont'd.)

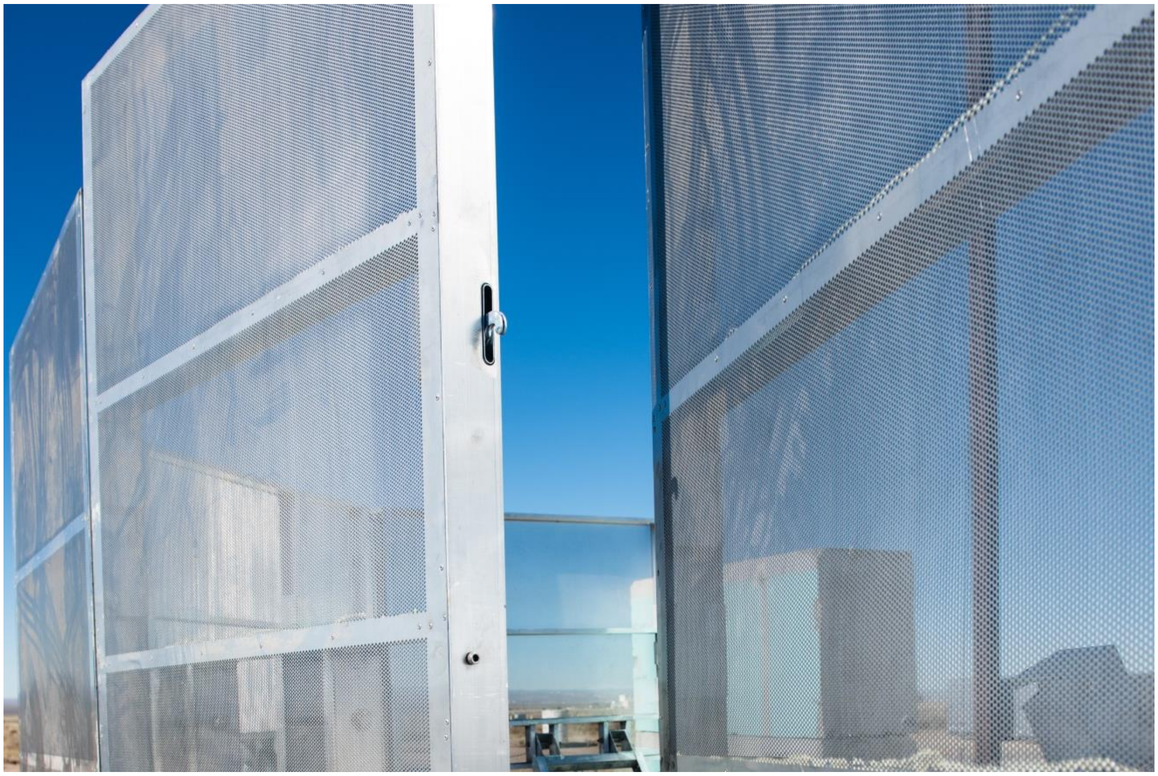


Figure 26 Upper quick lock latch on an upright in the latched position. During deployment the quick lock would not be in the latched position until the adjacent upright was in position. The female quick lock side not shown

Figure 27 Deployment team member using the hex wrench to latch the quick lock between two uprights

Adapter components, hinges, and termination components can also be attached to a straight section. These components are not supported by a base. Uprights can also be attached together without the use of a base as shown in Figure 28. This configuration is not recommended unless a vertical height change is necessary. The uprights, hinges and adapters are capable of 8-in. vertical height changes at each interface. There are two male quick locks latches, and three pairs of female receivers for the latches, each 8 in. offset from one another for up and down vertical height changes. These are primarily used for deployment over stairs, slopes, and curbs.


Figure 28 Upright component without a base

4 DEPLOYMENT EFFICIENCY EVALUATION

4.1 Test Logistics

The deployment efficiency tests (tests 1-5) were performed on November 29th, 2016 by SNL personnel at the Central New Mexico Community College (CNM) campus (Figure 29). One deployment efficiency test (test 6) was performed at SNL test Site 9920 on November 30th, 2016.

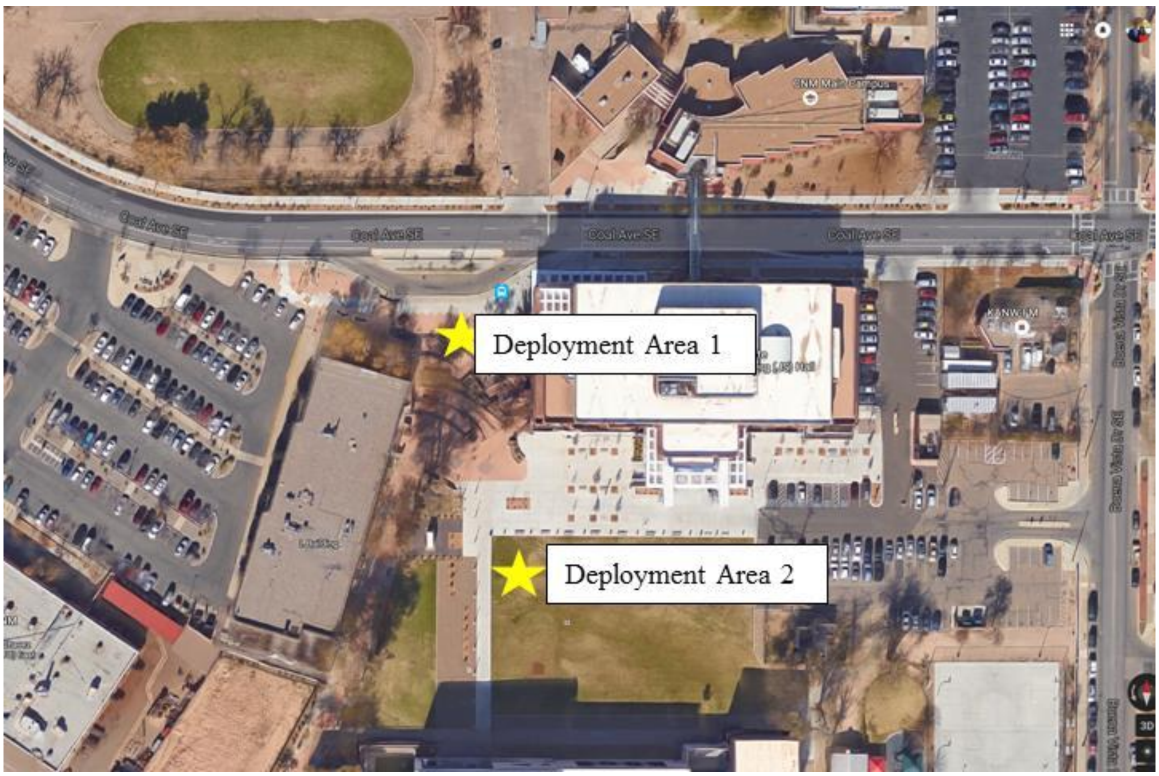


Figure 29 Deployment efficiency test location at Central New Mexico Community College campus in Albuquerque NM

CNM was chosen for the test location because the campus possessed multiple topologies of interest for the deployment testing. Specifically, CNM campus had stairs, concrete slopes, grassy slopes, flat concrete, flat grass, and a drainage ditch. The number of TAP barrier components provided to SNL is listed in Table 5. Two sets of the leveling tools and hex wrenches were also provided. The tests were limited by the number of TAP barrier components that were provided for testing. Because only four adapter components were provided, only approximately four stairs could be traversed during any specific deployment depending on the height/width of the step. This played a significant role when choosing deployment areas. Similarly, a limited number of turns were possible due to the limited number of hinge components. Furthermore, a single termination (male) component was provided, which affected the barrier effectiveness setup. The setup could not be terminated on one side using a standard termination component. The lack of two termination components did not affect the deployment efficiency evaluation, because no termination component was assembled during deployment efficiency testing.

Table 5 Total number of components provided to SNL for testing

Component	Quantity
Upright (hybrid, prototype, and production)	23
Base	23
Hinge	4
Adapter	4
Spikes	24
Termination component (male)	1

4.2 Test Description

The test matrix for the deployment efficiency tests is shown in Table 6. The deployment efficiency tests were performed using teams of four as shown in Table 7. Tests 1 and 2 were performed simultaneously at the two different deployment areas. After completion of tests 1 and 2 the teams switched deployment areas and performed tests 3 and 4 simultaneously. The teams were not allowed to talk or observe the tear down of the barrier configuration at the alternate test site. For tests 3 and 4 the teams had the experience of the prior deployment but at a different location and in a different configuration. Tests 5 and 6 were used to determine the speed of deployment under ideal conditions on grass and concrete respectively. The team members used for test deployments 5 and 6 all had participated in tests 1 through 4 and had experience with the barrier; however, composition of the teams was varied between tests. The time required for barrier tear down was also recorded subsequent to the deployment setup of test 5.

Table 6 Deployment efficiency test matrix

Test Number	Test Location	Test Date	Team	Team Experience	Maneuvers/Setup
1	Area 1	11/29/16	1	No experience	30ft concrete, stairs, 90-degree turn, incline
2	Area 2	11/29/16	2	No experience	70ft, grass, dips/hills, 90-degree turn
3	Area 1	11/29/16	2	Experienced	Same as test 1 (different team)
4	Area 2	11/29/16	1	Experienced	Same as test 2 (different team)
5	Area 2	11/29/16	3	Experienced	50ft, grass, flat surface, straight setup
6	Site 9920	11/30/16	4	Experienced	50ft, concrete, flat surface, straight setup

Table 7 Deployment efficiency test teams

Team Number	Team Member 1	Team Member 2	Team Member 3	Team Member 4
1	Steve Hill	Fred Snoy	Stephen Neidigk	Zak Wilson
2	Steve Highland	Ethan Tanner	Terry Hogan	Tom Rice
3	Steve Hill	Terry Hogan	Fred Snoy	Zak Wilson
4	Steve Hill	Stephen Neidigk	Tom Rice	Fred Snoy

The deployment efficiency team members were given the TAP barrier field manual, website animated instructions, and deployment video 24 hours prior to the test. The team members were asked to spend one hour reviewing the deployment material. The TAP barrier field manual was also provided to the deployment teams prior to and during the testing for reference as needed. While relatively straightforward, the TAP barrier assembly has an inherent learning curve. In order to quantify the learning curve by bounding the upper limit of assembly time, the teams were not given any hands-on experience with the barriers prior to the first tests.

After tests 1 and 2 were completed, both teams had significant experience setting up the barrier. Tests 3 and 4 repeated tests 1 and 2 with different teams, and the results will show there was a significant improvement in the barrier deployment speed that can be attributed to experience. Although limited in the number of data points, the repeat tests allow for some quantification of the improvement in deployment speed as experienced is gained. The barriers were initially staged 25 to 75 ft away from the deployment for tests 2 and 4 as shown in Figure 30. The barriers were initially staged 25 to 50 ft away from the deployment area during tests 1 and 3 as shown in Figure 31. This distance will generally affect the deployment speed, as it is the distance the barriers must be carried prior to deployment.

Figure 30 Barrier staging for tests 2 and 4

Figure 31 Barrier staging for tests 1 and 3

Test conditions were relatively cold, with a high of 36^{o} to 41^{o}F, cloudy and light rain at times during deployment evaluation testing on November 29th, 2016. The wind was generally less than 15 mph and had little effect on testing. Test conditions during deployment evaluation testing on November 30th, 2016 at Site 9920 (and barrier efficiency testing) were also cold with a temperature ranging from 32^{o} to 36^{o}F and sunny. The wind was again generally light, and had little effect on the testing. The cold weather forced the deployment teams to wear bulkier clothing and insulated work gloves, which played a factor in the overall deployment speed. Deployment teams also wore safety shoes for injury protection.

4.3 Test Configurations

This section shows the various TAP barrier configurations arrayed during deployment efficiency testing.

Figure 32 A 45-degree turn layout during deployment efficiency testing

Figure 33 A wide 90-degree turn during deployment efficiency testing

Figure 34 Compact 90-degree turn during barrier effectiveness testing

Figure 35 Adapter component assembled over stairs during deployment efficiency testing

Figure 36 Adapter component assembled over stairs during deployment efficiency testing (cont'd.)

Figure 37 Simulated curb/median setup during barrier effectiveness testing

Figure 38 TAP barrier deployed up a slope during deployment efficiency testing

Figure 39 TAP barrier deployed over a drainage slope during deployment efficiency testing

4.4 Test Results

Table 8 highlights the overall time of the deployment for each deployment test. Tests 1 and 2 required significantly more time than tests 3 and 4, which were identical tests with the exception of the team members and the team experience. Both teams significantly increased their deployment speed during their second deployment effort, suggesting that the increase in speed was mostly attributable to experience and less so the skill of one deployment team compared to the other. The decrease in overall deployment time was greater than 50% in both cases. Certainly team dynamics can play a role in the deployment speed, but the results suggest that a primary component is experience in deploying the barriers and that a team that has overcome the TAP barrier learning curve may be greater than twice as fast during deployment as a novice user. This has important training implications to any potential users of the TAP barrier system that may need to rapidly deploy the barriers. The experience level indicated in Table 8 is subjective, as experience is continually gained over the course of the deployment efficiency evaluation. Novice is intended to define a person who has had no hands-on experience prior to the beginning of the deployment test. Experienced is intended to define a person who has had hands-on experience prior to the beginning of a deployment test. Therefore, teams 1 and 2 both are labeled experienced after having completed tests 1 and 2, respectively. Photographs of the full test setup for tests 1 and 2 are shown in Figure 40 and Figure 41.

Table 8 Deployment overall time results

Test #	Test Location	Team #	# of Barriers	Maneuvers/ Setup	Experience	Time (min:sec)
1	Area 1	1	7 uprights, 6 bases 3 steps, 2 hinges	30ft concrete, stairs, 90-degree turn, incline	Novice	51:17
2	Area 2	2	15 uprights, 15 bases, 1 hinge	70ft, grass, dips/hills, 90-degree turn	Novice	58:01
3	Area 1	2	7 uprights, 6 bases, 3 steps, 2 hinges	Same as test 1 (different team)	Experienced	24:00
4	Area 2	1	15 uprights, 15 bases, 1 hinge	Same as test 2 (different team)	Experienced	36:14
5	Area 2	3	13	50ft, grass, flat surface, straight setup	Experienced	26:20
6	Site 9920	4	13	50ft, concrete, flat surface, straight setup	Experienced	23:12

Figure 40 Test 3 setup near completion (test 1 setup similar)

Figure 41 Test 2 setup near completion (test 4 setup similar)

Tests 5 and 6 were used to determine speed of deployment under relatively ideal conditions on grass and on concrete. The tear-down speed was also determined during test 5. During these tests only straight sections (base assembly and uprights) were deployed in a straight line. The deployment teams for these tests were a mixture of members from teams 1 and 2. All team members had experience from the previous tests.

4.4.1 Analysis

Test 1

Figure 42 shows barrier deployment from test 1. The deployment team primarily had difficulty due to the height of the stairs. The adapter components only allow for 8-in. vertical height adjustments at a single interface and the stairs did not have an overall height change that was a factor of 8 in. Therefore, the stair components did not fit perfectly, and had to be adjusted multiple times until the slope of the ground above the stairs met the adapter component at a more ideal height. It was found throughout testing that the stairs were the most difficult deployment topology.

Test 1 timeline data is shown in Figure 43 and show only two data points for the deployment of the stairs, which represent the start and end points for putting up the series of steps. The deployment team was forced to restart the steps by taking apart previously completed sections. For this reason, it was not feasible to break the stair deployment into more than a start and stop time. It took nearly 27 minutes to complete the 3 stairs due to starts, stops, and restarts. Using the two data points, over the distance of the three steps and two straight sections on either side, the setup speed was roughly 0.14 ft/min. Test 1 used a novice team suggesting that the observed speed represents a lower limit at which the TAP barrier is deployed over stairs. In test 1 the team completed the wide 90-degree corner turn using a straight section in between the two hinge components. This provides the sturdiest 90-degree turn as compared to a sharp 90-degree turn, which requires one or two hinge components without a base between the two.

Figure 42 Test 1 deployment

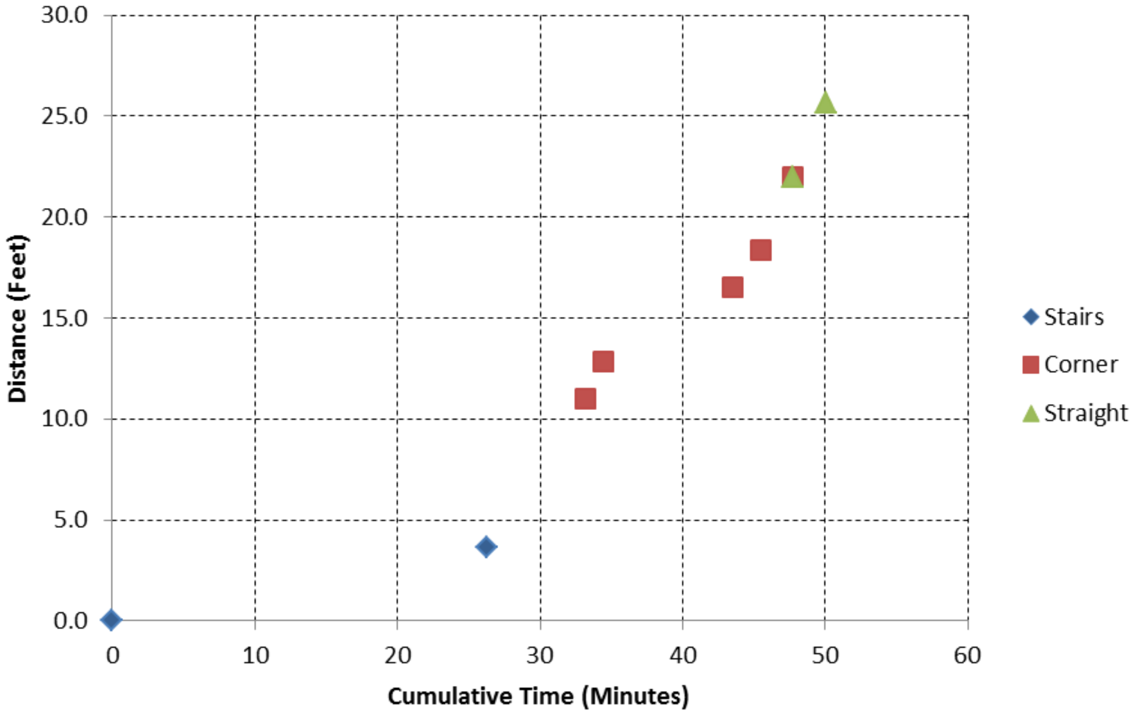


Figure 43 Plot of distance versus time during test 1 barrier deployment on the concrete steps

Test 2

Figure 44 shows barrier deployment from test 2. The deployment team primarily had difficulty with one upright that would not latch to the upright next to it. The latching issue was due to the quick lock not having been turned to the correct position prior to deployment. This issue arose more than once throughout the deployment process. The quick locks must be properly "cocked" prior to latching or the mechanism will not fully catch. Generally, this was not an issue, but on more than one occasion the quick lock would slip and would not latch. This issue occurred on the sixth straight section deployment and required a disassembly costing the team roughly 15 minutes of total time. Including the time spent deploying the sixth barrier the speed of deployment was approximately 0.95 ft/min overall. If the time spent on the sixth barrier is discounted the speed of deployment was approximately 1.2 ft/min. Test 2 also used a novice team during deployment, and the speed was shown to increase over the course of the testing series.

Figure 44 Deployment efficiency evaluation test 2

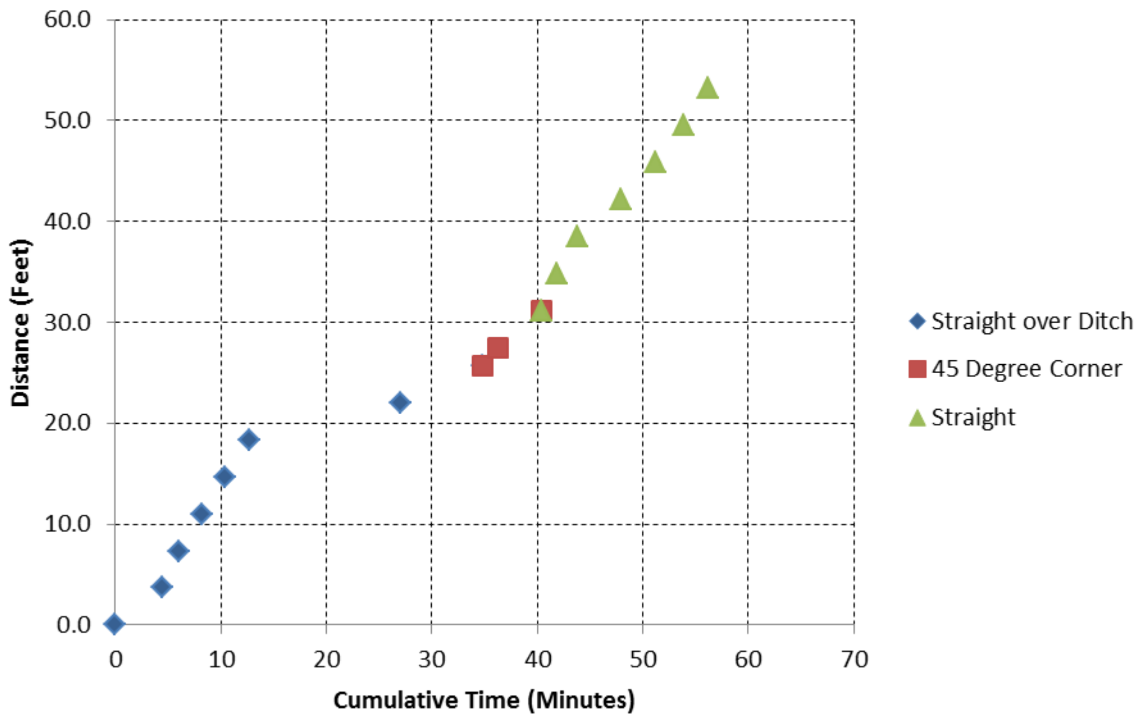


Figure 45 Plot of distance versus time during test 2 barrier deployment on the grass field

Test 3

Test 3 was a repeat of test 1 with a different, experienced team. A significant decrease in overall time for deployment was observed compared to the novice team as previously noted. The average deployment speed for the entire test duration was 1.5 ft/min from start to finish. Figure 46 shows the data points of each individual straight section, corner, and adapter being erected. It is clear from the slopes of Figure 46 that the slowest portion of the deployment was again the adapter components over the stairs. This occurs for two reasons. First, the adapter components are one-fourth the width of regular uprights, but still require the same quick locking mechanism for each. Therefore, more time is spent performing alignment per unit width, which will decrease the speed. Secondly, the stairs are more difficult to traverse than flat terrain due to their unevenness and the limited flexibility in the vertical height adjustment of the adapter components. It should be noted that the deployment team in test 3 did not perform a wide 90-degree turn with a full straight section between the two hinge components. Instead, the team placed two hinged components together side by side to obtain the 90-degree angle. This creates a weaker corner, but had little effect on the overall deployment time because the straight section that was not used between the hinges to make the full 90-degree turn was added to the end so that the same number of components was used as in test 1.

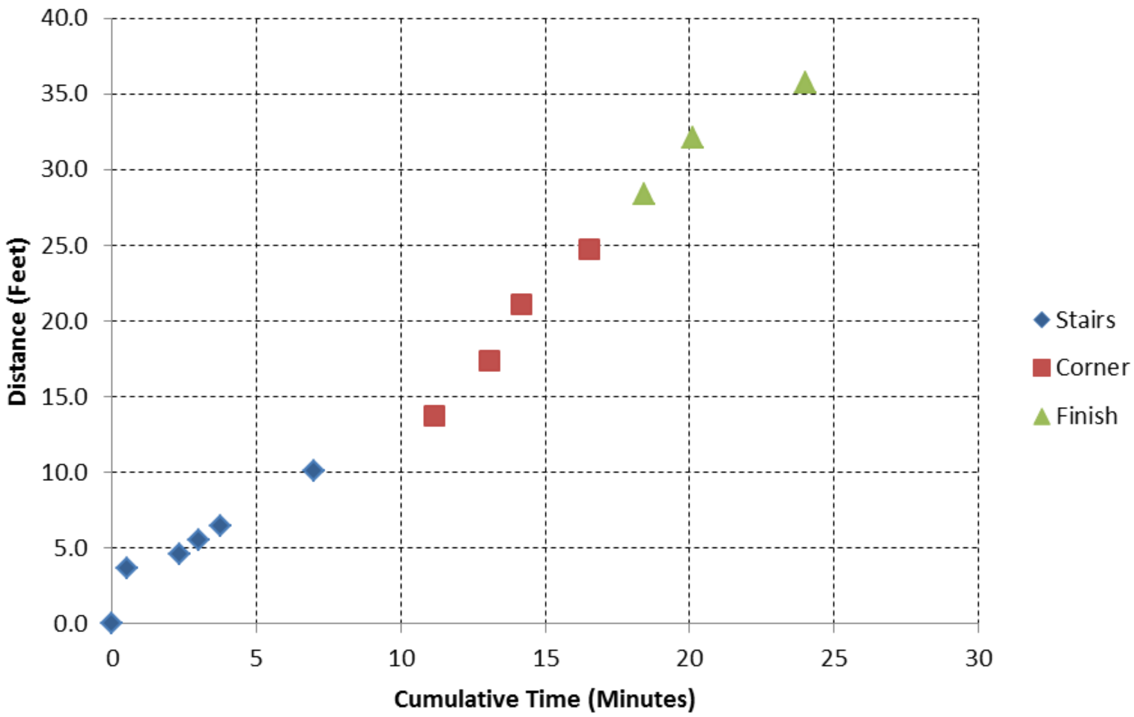


Figure 46 Plot of distance versus time during test 3 barrier deployment on the concrete stair section. The best fit speed was 1.03 ft/min over the stairs with a goodness of fit value of 0.98. The best fit speed was 2.09 ft/min while deploying the corner section with a goodness of fit value of 0.98. The best fit speed was 1.25 ft/min while deploying the final three barrier sections with a goodness of fit value of 0.95

Test 4

Test 4 was a repeat of test 2 with a different, experienced team. Similar to the comparison between tests 1 and 3, a significant decrease in overall time for deployment was observed compared to the novice team. The average deployment speed for the entire test duration was 1.65 ft/min from start to finish. Figure 47 shows the data points of each individual straight section and hinge component being erected. It is clear from the slope in Figure 47 that the overall speed was relatively linear. This suggests that the hinges had a comparable deployment speed to the straight sections. The last straight section required the longest amount of time, ignoring this data point the speed was approximately 1.8 ft/min for the deployment. After testing it was observed, that one of the components in the setup was not properly latched in one spot. The time required to fix this was not included, as it would have required disassembly. See the highlighted area in Figure 48 indicating where the bottom quick lock did not latch.

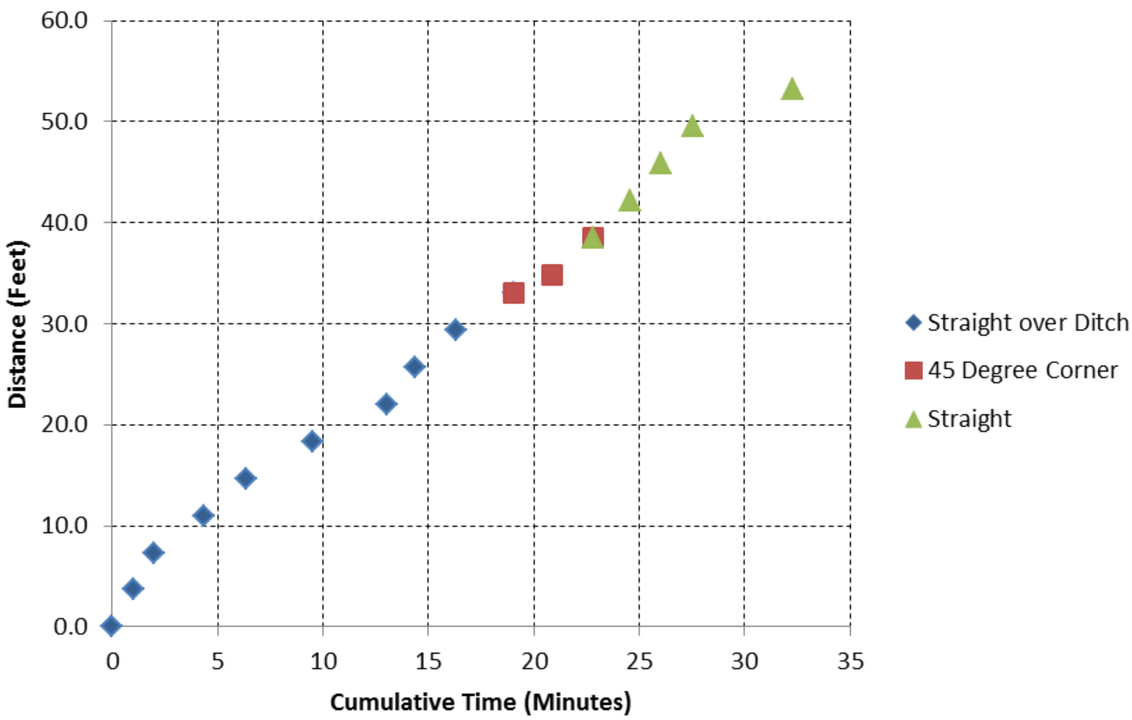


Figure 47 Plot of distance versus time during test 4 barrier deployment on the grass field

Figure 48 Test 4 configuration showing the component that was not properly latched due to issues with the quick lock not catching

Test 5 – Straight Deployment on Grass

Figure 49 shows a plot of distance versus time for test 5 of the deployment efficiency test series. Thirteen straight sections were deployed in a straight line on grass, each straight section measures 44 in. in width resulting in an overall TAP barrier length of slightly less than 48 ft. The time required to place and attach each straight section was recorded and is plotted in Figure 49. The slope of the best-fit line to the data represents the average speed for barrier deployment in ft/min. The average speed for a straight line deployment on grass was 1.7 ft/min, which is similar to what was seen in test 4. Figure 50 similarly plots the distance versus time for tear down of the barriers from test 5. The average speed for the take-down process was 3.7 ft/min.

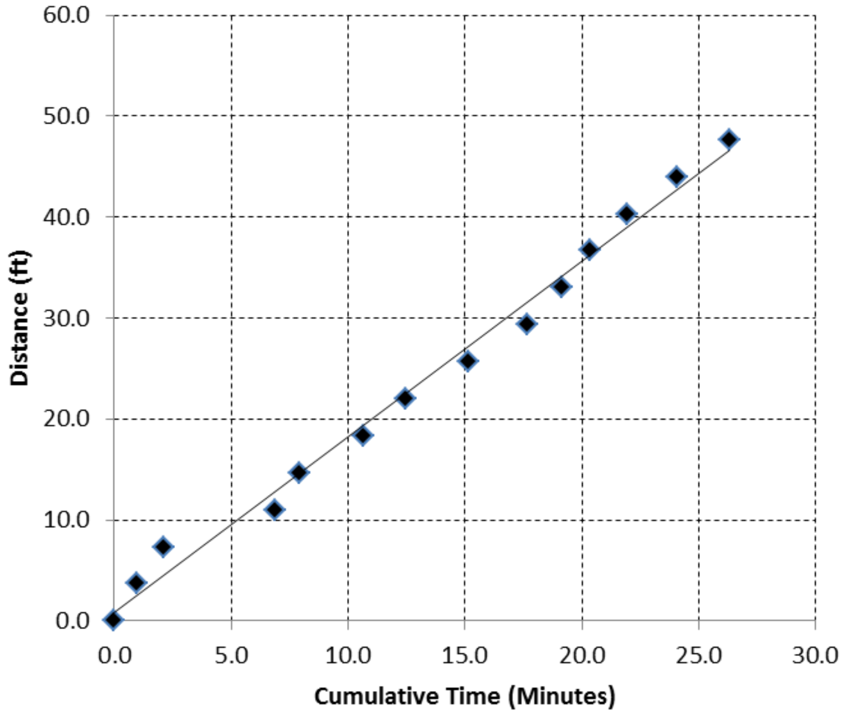


Figure 49 Plot of distance versus time during test 5 barrier straight setup on grass. The best fit speed was 1.74 ft/min with a goodness of fit R^2 value of 0.99

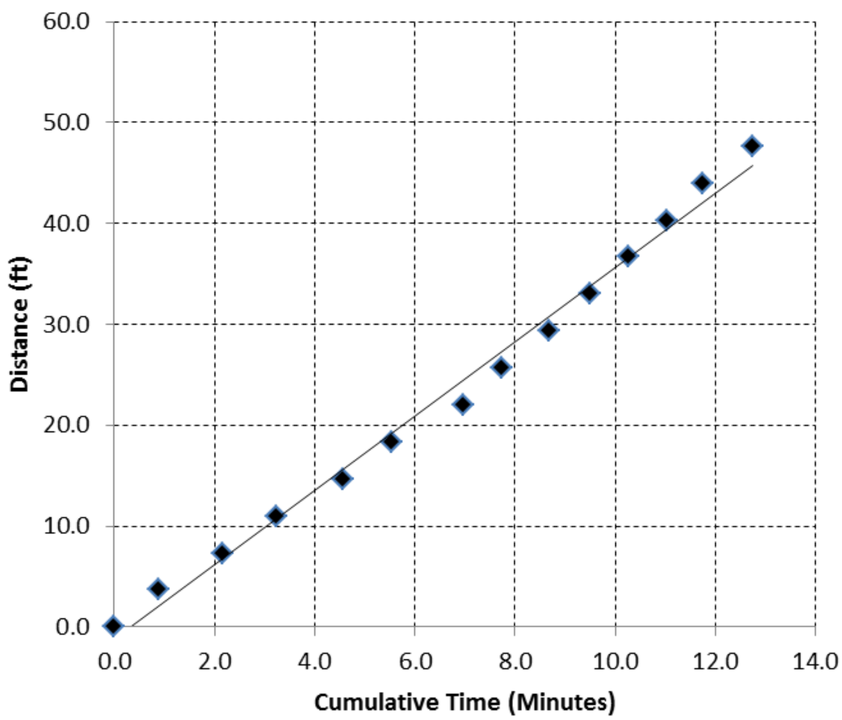


Figure 50 Plot of distance versus time during test 5 barrier straight tear-down on grass. The best fit speed was 3.69 ft/min with a goodness of fit R^2 value of 0.99

Test 6 – Straight Deployment on Concrete

Test 6 was similar to test 5 but performed on concrete; the results are shown in Figure 51. The average speed for deployment on concrete was approximately 1.9 ft/min. With an experienced team such as the one performing test 6, generally the most critical factor affecting the speed of deployment is the alignment of the uprights so that the quick locks can be latched.

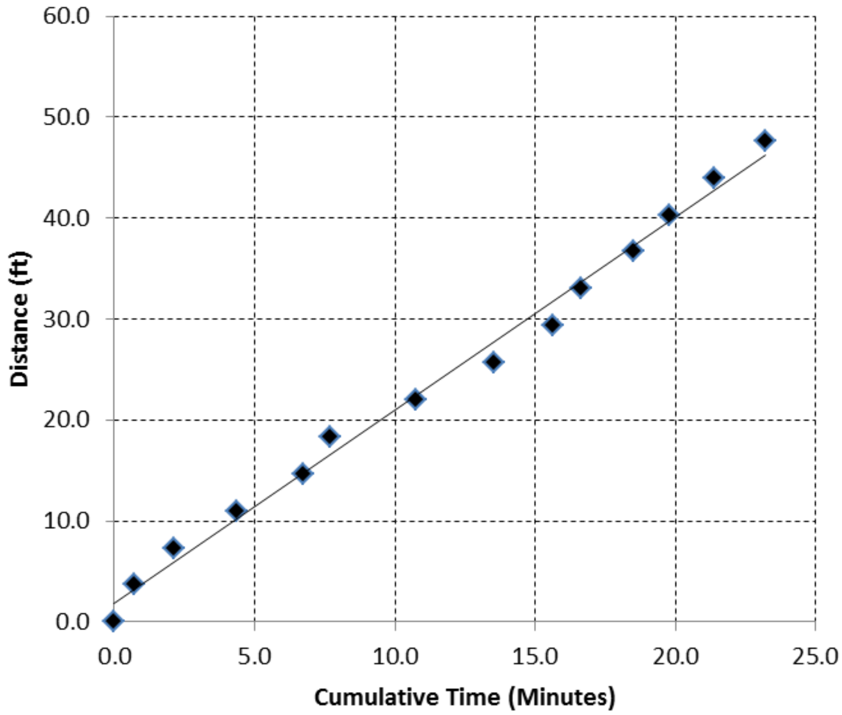


Figure 51 Plot of distance versus time during test 6 barrier straight setup on concrete. The best fit speed was 1.92 ft/min with a goodness of fit R^2 value of 0.99

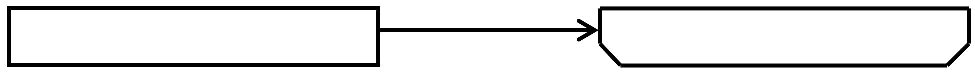
4.4.2 Recommendations

The deployment teams were asked to write down recommendations/modifications that they would consider for improving the TAP barrier system.

Modifications to Barriers

- Addition of handles to the sides for easier transportation of the TAP barrier system.
- Alignment pins on all upright components (Some upright components did not have alignment pins, making alignment for latching with other uprights more difficult.)
- Greater vertical variation at upright interfaces. Currently the system can rise and fall 8" at each interface. More options in vertical variation would make stairs and slopes easier to deploy on.
- Visual markers on the outside of upright panels for alignment.
    - Window or indicator to visually see when upright locks are in place
- Some indication to verify lock has fully latched to the upright next to it.
    - Contact Gauge

- Bevel the uprights at 45 degrees to slide into the base easier. Will fit into the opening in the base more readily (see graphic).



- Add a threaded jack screw to level the rear of the base.
- Improve the sliding mechanism on the adjustment feet; many do not readily slide into place.
- Better installation tools. Include several pry bars, one broke during deployment. Large sliding C-clamps to hold uprights together quickly.

Modifications to Instructions

- The instruction manual should give more guidance to demonstrate installation on uneven terrain that demonstrates that the barriers do not need to sit flush with the ground.
- The instruction manual/video does show an order of operation for the deployment, but should emphasize this in greater detail, for instance, locking the upright into the base prior to locking the upright to the adjacent upright. It is possible to deploy the barrier in either order; however one method appears less time consuming.
- The instructions indicate a “compact 90-degree turn” that is not possible with some hinge components that were received.
- If possible, create video instructions rather than written instruction for deployment over different types of terrains that will reduce the learning curve for each, that is, topology-specific instructions.

4.4.3 Conclusions

The deployment efficiency evaluation led to the following conclusions regarding the TAP barrier system:

- The deployment speed for an experienced team (those who have had prior hands-on experience with the TAP barrier system) was approximately 1.9 ft/min on level concrete in a straight path.
- The deployment speed for an experienced team (those who have had prior hands-on experience with the TAP barrier system) was 1.7 ft/min on level grass in a straight path.
- The speed of a deployment for a given deployment team nearly doubled after the team had gained experience from a previous deployment test. Hands-on training of deployment teams in best practices for setup of the TAP barrier will significantly improve observed deployment teams, and result in more consistent/stable barrier setup.
- Novice team overall deployment speeds ranged from 0.5 ft/min (Deployment Area 1) to 0.95 ft/min (Deployment Area 2). Deployment Area 1 contained stairs that tended to be more difficult than other deployment topology.
- The stairs were the most difficult topology to traverse using the TAP barrier system, ranging from 0.14 ft/min for a novice team to 1 ft/min for an experienced team (stairs only). The novice team had tremendous difficulty with the stair section, requiring multiple re-constructions. The primary difficulty was due to the limitations in overall height change with each adapter component.

- The speed of the deployment team over a long distance was at times much faster than the average speed. Often, a single barrier or two would take much longer than the rest, which would reduce the average speed. The biggest issue was with quick locks that were not properly cocked into position prior to setup. If the latch was not properly cocked into position, it would not properly latch and would require disassembly. Other common issues were alignment over uneven terrain.
- Using the flexibility of the TAP barrier bases to traverse the ditch resulted in a significant bowing effect. The recommended method is to use height changes prior to the slope so that the base meets (or gets close to) the slope at each connection. This results in a more stable setup, but does create gaps, which are generally less than 8 in. tall, between the bottom of the barrier and the grass surface.

5 ATTACK TESTING EVALUATION

5.1 Test Logistics

The attack testing phase was conducted at SNL Site 9920 on November 30th, 2016 by SNL personnel. Twenty separate testing events were conducted as listed in Table 9.

Table 9 Barrier effectiveness test matrix

Test Number	Test Location	Test Date	# Of Attackers	Attack Technique
1,2	Site 9920	11/30/16	1	Climb: unaided w/ base
3,4	Site 9920	11/30/16	2	Climb: aided w/ base
5	Site 9920	11/30/16	1	Climb: ladder w/ base
6	Site 9920	11/30/16	12	Breach: coordinated push w/ base
7,8	Site 9920	11/30/16	1	Breach: projectile/masonry
9	Site 9920	11/30/16	2	Breach: lift w/ jack
10,11	Site 9920	11/30/16	1	Breach: improvised ramming tools
12	Site 9920	11/30/16	N/A	Breach: improvised incendiary
13	Site 9920	11/30/16	1	Breach: ram/post-incendiary
14	Site 9920	11/30/16	1	Climb: unaided, no base
15	Site 9920	11/30/16	2	Climb: aided, no base
16	Site 9920	11/30/16	12	Breach: coordinated push, w/o base
17	Site 9920	11/30/16	1	Breach: peel mesh/post-incendiary
18	Site 9920	11/30/16	1	Breach: peel mesh
19	Site 9920	11/30/16	1	Breach: separate hinged corner
20	Site 9920	11/30/16	1	Climb: defeat spikes

Site 9920 provided a secure facility with a large concrete pad, suitable test support facilities, and ample sightlines for documentary photography. The initial setup of the barrier as configured for attack testing consisted of a mixture of panels and configurations intended for specific tests, with the end panels bolted into massive modular blocks of concrete as shown in Figure 52.

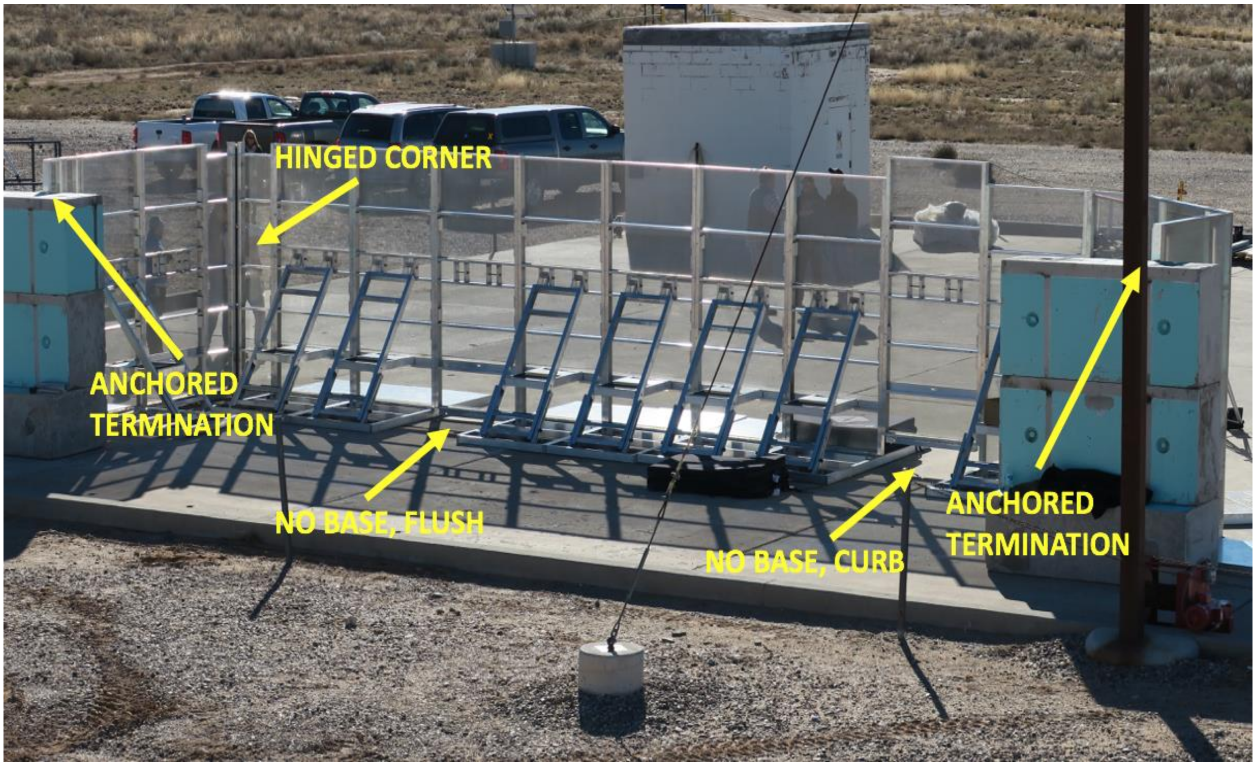


Figure 52 Attack testing configuration at Site 9920 Sandia National Laboratories, NM

The attackers chosen to perform the attacks varied in skill and ability. Most of the attacks were performed by either Ethan Tanner or Derek Farr. These two attackers are at the upper threshold of a potential adversary in a riot scenario due to their training background. It may be argued that having more skilled attackers perform many of the attacks is not representative of the true mob threat, but it is not feasible to perform each destructive test with a sample size capable of giving a true threat distribution. Therefore, it was determined to err on the side of caution with a more skilled attacker to perform the tests. Furthermore, as the riots become larger in number, the odds of having a more advanced attacker within the group continue to increase. The coordinated push scenario used attackers from all skill levels, many of whom have no formal training as would be expected in a mob/riot scenario.

5.2 Test Description

A schedule of tests was established containing representative climbing, breaching, and thermal attacks. Time and logistical support was set aside from the schedule to accommodate additional or follow-on tests per customer requests or as required to clarify completed test results. Two timekeepers were used and the lower attack time recorded. No rehearsals or planning were permitted other than specific to test safety. Climb attacks were assessed as successful if the attacker reached the protected side of the barrier and completion times recorded (see Table 10). Breaching attacks were assessed as successful if, at a minimum, an opening was created permitting the passage of the elliptical gauge through the breach and then assessed for completion time. The elliptical gauge is roughly 16” in the semi-major axis and 9.125” in the sem-minor axis. Distance measurements were taken of movement of panel bases during coordinated shove attacks. Specific attack tests and results are discussed in the following sections.

Figure 53 Tools available during attack testing

Tests 1 and 2

Role players were tasked with individually climbing over the barricade at a panel supported by a base (Figure 54). Role players were free to choose either a running or standing approach to the climb. Both role players chose a running start and were successful in completing the climb. Time started when role players initially contacted the barrier and ended when both feet contacted the ground on the far (protected) side of the barrier. In the absence of anti-climb spike arrays on top of the barrier, the role players were able to climb the barrier without difficulty.

Figure 54 Barrier effectiveness evaluation test 1

Tests 3 and 4

Role players were tasked with climbing over the barricade at a panel supported by a base using an assisted-climb method wherein one role player uses his body to form a climbing aid for his partner (Figure 55). In the absence of anti-climb spike arrays on top of the barrier, the role players were able to climb the barrier without difficulty.

Figure 55 Barrier effectiveness evaluation test 3

Test 5

A single role player was tasked with climbing over the barrier using a ladder as a climbing aid. The ladder was a 12-ft, A-frame ladder, leaned up against the surface of the barrier (Figure 56). In the absence of anti-climb spike arrays on top of the barrier, the role players were able to climb the barrier without difficulty. Had the spike arrays been present, additional delay would have resulted.

Figure 56 Barrier effectiveness evaluation test 5

Test 6

A group of 12 role players of varying sizes and degrees of physical fitness were tasked with shoving against the barrier using only their bodies. To simulate a larger crowd, role players were confined to a narrow frontage (Figure 57). After repeated attempts, the simulated attackers were able to defeat the barrier.

Figure 57 Barrier effectiveness evaluation test 6

Tests 7 and 8

Two attacks were combined into a single test during which a single attacker hurled two different types of masonry brick against the surface of the barrier with the intent of creating a breach (Figure 58). After prolonged effort, hurled masonry objects pierced the surface screen and created a breach.

Figure 58 Barrier effectiveness evaluation test 7

Test 9

Role players attempted to create a breach beneath the barrier using an automotive jack to lift the barrier (Figure 59). The barrier at the attack point was configured as though transiting a raised curb. The distance between the surface of the simulated curb and the bottom of the panel provided a gap of sufficient height to admit the lifting surface of the automotive jack (Figure 60). Attackers were able to lift the barrier sufficient distance to admit the elliptical gauge.

Figure 59 Hydraulic jack lift from barrier effectiveness evaluation test 9

Figure 60 Barrier effectiveness evaluation test 9

Tests 10 and 11

Single role players were tasked with creating a breach on a barrier panel using a series of improvised ramming tools to penetrate the surface of the barrier. A selection of improvised tools consisting of 2-in. x 4-in. lumber, steel pipe, and a metal sign post, were available to a single attacker to employ as he wished. Attackers quickly discarded the lumber as ineffective, reporting that while slow to damage the barrier surface, the lumber imparted significant vibration to the attacker, making it difficult to use (Figure 61). The metal tools, a section of engineer stake and a section of square sign post stanchion, were more effective and comfortable to use (Figure 62). The most effective tactic appeared to be perforating the outer screen then prying against the remaining screen using the structure on the protected side of the barrier for leverage. Using this and other techniques, the attackers were able to create a breach through which the elliptical gauge was capable of passing.

Figure 61 Barrier effectiveness evaluation test 11


Figure 62 Barrier effectiveness evaluation test 11

Test 12

To examine the effects of a "Molotov cocktail" type device against the barrier, a simulated improvised incendiary device was placed against the barrier surface, ignited, and allowed to burn out (Figure 63). This attack, by itself, did not defeat the barrier but did weaken the structure of the burned areas (see Thermal section).

Figure 63 Barrier effectiveness evaluation test 12

Test 13

As a follow-on test to test 12, a single attacker attempted to breach the barrier using only a section of sign post stanchion. The attacker was able to create a breach capable of admitting the elliptical gauge in less time than in tests 10 and 11; however this was probably attributable more to attackers gaining proficiency with this attack technique.

Test 14

A single role player was tasked with an unaided climb of the barrier at a panel unsupported by a base section (Figure 64). This configuration essentially adds the height of the base section to the top of the barrier for climbing attacks, making it more difficult. In the absence of anti-climb spike arrays on top of the barrier, the role players were able to climb the barrier without difficulty.

Figure 64 Barrier effectiveness evaluation test 14

Test 15

Role players were tasked with climbing over the barricade using an assisted-climb method at a panel unsupported by a base. The assisted-climb method was the same as in tests 3 and 4, specifically; one role player uses his body to form a climbing aid for his partner. In the absence of anti-climb spike arrays on top of the barrier, the role players were able to climb the barrier without difficulty.

Test 16

A group of 12 role players of varying sizes and degrees of physical fitness were tasked with shoving against the barrier using only their bodies. The panels at the point of attack were unsupported by bases. As with test 6, role players were confined to a narrow frontage to simulate a larger crowd. Without the bases providing support, the crowd was quickly able to push through the barrier.

Test 17

Based on observations during the incendiary device test of metal deformation and a possible secondary burn of adhesive material, a follow-on to test 12 was conducted. This consisted of a single attacker attempting to peel the exterior skin away from the frame using a crowbar at the burned area of the barrier. The attacker was able to insert the point of his crowbar into a gap between the barrier surface screen and the frame beneath and subsequently pull the surface material away, creating a breach.

Test 18

A follow-on to test 17, a single attacker attempted to peel the exterior skin away from the frame using a crowbar at an unburned area of the barrier for a comparison time. There was no perceptible gap between the surface mesh and the frame, thus the attacker was unable to conduct the attack.

Test 19

This test consisted of a single attacker using a selection of tools (Figure 65) to create a breach on a corner hinged component of the assembled barrier. The attacker tried prying the panels apart using the crowbar then attacked the junctions between the panels using the masonry hammer and hand sledge. Finally, the attacker chose the heavy sledge and by swinging it repeatedly against the barrier frame near the junction points, was able to break the connections between the panels and create a breach capable of admitting the elliptical gauge.

Figure 65 Tools used in barrier effectiveness evaluation test 19

Test 20

In test 20 a single attacker attempted to defeat the spikes while they were attached to the upright of an assembled barrier. The attacker chose to use the metal post from the suite of tools available to bend the spikes down and render them ineffective. The metal post was effective at bending the spikes, but it is unclear whether bending the spikes forward would benefit a potential climber. For safety considerations, no attackers were allowed to climb over an upright with spikes. In order to perform this attack the attacker needed to be raised off of the ground, which would be difficult to coordinate during a riotous attack. Still, the test showed this to be a potential defeat method of the spikes. The back row (defense side) of the spikes presented a greater challenge in terms of bending. Figure 66 shows the attacker using the metal post to bend the spikes during test 20.

Figure 66 Barrier effectiveness evaluation test 20

5.3 Test Results

Table 10 lists the time results of attack testing.

Table 10 Table of attack test time results and description

TEST #	DESCRIPTION	TIME *mm.mm*	BREACH (Y/N)	COMMENTS
1,2	Unaided climb	00.10	Y	N/A
3,4	Assisted climb	00.16	Y	N/A
5	Ladder climb	00.18	Y	N/A
6	Coordinated push	10.75	N	N/A
7,8	Projectile	03.93	Y	Ellipse passed through opening
9	Lifting	01.11		Stopped for safety

TEST #	DESCRIPTION	TIME *mm.mm*	BREACH (Y/N)	COMMENTS
10,11	Ram	01.95	Y	2-in. x 4-in. lumber (initial 60 sec) was ineffective, sign post effective, ellipse passed through opening
12	Incendiary	N/A	Y	[12.46-min. burn time] mesh peeled from frame
13	Ram, post-incendiary	00.45	Y	Ellipse passed through opening
14	Unaided climb: no base	00.45	Y	N/A
15	Assisted climb: curb	00.25	Y	N/A
16	Coordinated push: floating	00.23	Y	Two panels w/ no base attached between panels with bases
17	Post-incendiary: peel mesh	03.36	Y	Crowbar used to peel away surface mesh following the prescribed burn
18	Post-incendiary: control	03.50	N	N/A
19	Panel spread: corner panel	02.83	Y	Single attacker, combination of tools, including sledge and pry tools against corner hinge component.
20	Defeat spikes	N/A	Y	For demonstration purposes only, testing a variety of tools and methods

5.3.1 Analysis

Climbing

The approximately 9-ft height of the erected barrier is visually imposing and is a challenge to climb without aids. However, climbing aids are readily available in almost every environment and the deployed system would benefit greatly from installation of the spike arrays. Without the spikes the barrier can be readily climbed by those people capable of jumping high enough to reach the top and having strength enough to pull themselves over (or with the assistance of another). Surveys of the attackers indicate the presence of the spikes would dissuade attempts at climbing the barrier without first attempting to defeat the spikes. The spikes themselves proved difficult to defeat and efforts toward that end would be comparatively slow and cumbersome due to the height of the barrier and spike array. Panels erected without a base proved even more difficult to climb, in every other attack circumstance the absence of a base was to the detriment of the barrier.

Climbing attack testing was constrained by safety requirements insofar as the anti-personnel spikes were not installed on the test barrier, nor was any attempt made to simulate deployable crowd control measures such as chemical irritants or other less-lethal munitions. In the absence of these variables, climb test results can only indicate the relative difficulty of climbing the barricade as expressed by the success or failure of attempts and the amount of time elapsed during the efforts. As it is impossible to predict the physical skill, degree of motivation and/or improvised climbing aids that might be encountered during operational field deployments of the barrier, no inanimate climbing aids were used by the simulated attackers.

Breaching

Breaching attacks were limited in scope by postulated adversary capability based on customer feedback concerning intended field use of the barrier system. An adversary profile was developed intended to simulate an attacker possessing a high degree of motivation, varying degrees of physical fitness and limited technological capability and access to technical tools. Tools were selected based on items readily available in most urban environments for use as improvised breaching tools. These items included lengths of steel pipe; sign post stanchion, lumber, and commonly available hand tools such as sledge hammers and crow bars and an automotive jack. An evaluation tool was fabricated at SNL based on Department of State specifications. This tool was used as a gauge to determine a successful breach size.

Figure 67 Breach test using the hydraulic jack-lift during test 9

Mass shoving attacks were relatively ineffective in breaching the barrier at locations with a base present, but did cause significant barrier movement. Mass shoving attacks at unsupported locations were effective in breaching the barrier. With a base present the majority of attackers stand on the base while attempting to shove the upright which significantly reduces the effectiveness of the push.

The lifting by hydraulic jack similarly can be an effective attack path, especially at unsupported uprights with height change where the hydraulic jack can easily be maneuvered into place. In practice using the hydraulic jack requires solid footing for the jack to be placed under.

The projectiles effectively tore through the front screen and were capable of making a man passable hole. This process took several minutes and was not the quickest method. The improvised ram using a metal post representative of a sign post was significantly more effective.

Figure 68 Ellipse used to determine test completion during test 19

Thermal

The sole thermal attack consisted of a simulated Molotov cocktail type device placed against the barrier, ignited and allowed to burn out. The simulated device contained two liters of kerosene, poured over the surface of the barrier and captured in a shallow basin as it flowed downward. The flammable liquid burned for approximately 12.46 minutes and appeared to ignite a secondary source, possibly adhesive present between the surface mesh and the structures beneath. After all flames had self-extinguished, the barrier was doused with water to cool the heated surfaces for safety purposes before testing resumed on the burned area with tests 17 and 18. Close observation during the burn revealed surface mesh buckling, causing the mesh to pull away from the frame. The mesh returned to its original shape after the heat source was removed, however, subsequent testing indicated the heat had reduced the effectiveness of the burned area.

Figure 69 Mesh pulling away from the upright frame during thermal attack test

5.3.2 Conclusions

Analysis of the attack testing cycle results indicate a barrier system that is robust considering its' light weight and portability. The testing showed the following:

- In the absence of deployed spikes on top of the uprights, the barrier is highly susceptible to climbing attacks. Both single and two-person attacks readily traversed the barrier.
- The spikes are likely to significantly deter climbing without aids available. Tests were performed to defeat the spikes and it was shown that the defeat methods tested were relatively slow with undetermined benefit.
- Attackers with climbing aids (ladders, blocks, etc.) likely still may be able to defeat the barrier if it had spikes, but these tests were not performed due to safety considerations.
- Breaching via a coordinated push attack was relatively ineffective when performed on a supported upright, but was highly effective at an unsupported upright location (uprights without bases) which are likely to be present in most TAP barrier deployment layouts.
- The unsupported upright locations are likely to be the weak points in the TAP barrier system. Adapter components are similarly unsupported and potential weak points. **If at all possible the deployment team should avoid adjoining two unsupported straight uprights.**
- Lifting the barrier using a hydraulic jack is believed to be a viable defeat path although testing was stopped for safety slightly prior to completion. The unsupported barrier locations are again the most vulnerable locations to the hydraulic lift attack scenario.

- Breaching via projectiles and rams are both viable. A steel sign post is the most effective ram attack. Wood 2x4 was relatively ineffective. Projectile attacks are slow compared to the steel ram attack but are possible.
- The simulated Molotov cocktail thermal attack did little to affect the TAP barrier. It did cause some peeling on the front screen at the edges which gave way to prying attacks. The peeling was minor, and this attack path was relatively slow compared to the improvised steel ram.

5.3.3 Recommendations

After performing the barrier effectiveness testing, the following recommendations for the use and deployment of the TAP barrier are as follows:

- Without spikes, climbing is the most effective way to defeat the system. Spikes should be deployed when possible as they provide significant deterrence.
- Unsupported uprights are the weakest link in the TAP barrier system. Unsupported uprights should not be joined together if at all possible. These joints are susceptible to lifting and pushing attacks that are significantly less effective on uprights with bases supporting them.
- The termination components were not tested, but may play a significant role in the effectiveness of the barrier as a whole.

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