# Lead Shot Fabrics and Curtain Systems for Mitigating Lead Contamination at Shooting Ranges*

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## BACKGROUND

A recent Chemical and Engineering News article [C&EN, 9/26/06(2006) p. 97] has stated that gun users in the more than 12,000 military and sport shooting ranges in the United States introduce more than 60,000 tons of mostly spent lead ammunition in the environment each year. According to Dr. Xinde Cao an environmental chemist at the University of Florida, "Lead buildup in these ranges has become one of the largest influxes of lead in the environment". This environmental contamination is especially troubling because lead can easily migrate from the range site and into surface and groundwater systems. In response to this problem, all gun club sportsmen and women face an important challenge from the environmental contamination caused by spent lead shot that accumulates in the soil at skeet, trap and sporting clay ranges and the like. Lead contamination is a persistent threat to wildlife, natural habitat and water quality and therefore causes a potential health hazard to humans. Consequently, this problem has garnered the attention of national sportsman organizations, arms and ammunition manufacturers, environmental professionals and concerned citizens. (See "Getting the Lead Out" by Donald Hanson, which was first posted on the Massachusetts Department of Environmental Protection website in March 2000). From this Mass. DEP article, there is an obvious need for a technology leading to the minimization of lead shot contamination at skeet, trap and sporting-clay shooting ranges. So far, two very different technical approaches have emerged: (1) converting all ammunition from lead (metal) to steel or other type of material shot, and (2) the installation of barrier curtains at the shooting fields to prevent the lead shot from straying into unwanted areas. From a munitions viewpoint, steel shot is available but does not have the same shot trajectory and impact dynamics that lead shot has. Furthermore, steel shot does not treat the inner bore of shotguns too well. Inner barrel wear and scoring can result by using steel shot. Also, steel shots are more expensive than lead shots. Toward this end, the University of Massachusetts-Dartmouth (UMD) Textile Sciences Department has approached the lead shot contamination problem from the standpoint of developing special ballistic fabrics useful for fabricating barrier curtains. These fabric curtains and their support structure will now be applied to the containment of lead shot at sport shooting ranges. That is these curtains can be positioned at the shooting field so that they can shield lead pellets from entering the parts of the shooting range areas that are environmentally sensitive (e.g. wetlands) or are in rugged and poorly accessible terrain. In practice, such curtain systems are hung on poles or other such structures and positioned to serve as a back-drop for the stray lead pellets that are ejected during shooting range activities. As a result of hitting the fabric, the lead shot pellets will lose all or most of their kinetic energy and fall to the ground near the fabric. It is anticipated that the spent shot can then be collected on a

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matt fabric, sand or gravel bed so the lead can be recovered and recycled with overall minimal environmental impact on the surrounding areas.

At the start of this project, some general specifications regarding the fabric and support structure requirements were proposed by the UMD Lead Shot Curtain (LSC) project team. These are listed below:

(1) No permanent damage to the fabric material from multiple rounds of lead pellets shot from a shot-gun shooting at a distance of 100 yards (or less) from the target fabric.
(2) Minimum "bounce back" of the pellets upon impacting the fabric.
(3) Open fabric structure to minimize wind load on curtain.
(4) Curtain system easily deployed; easily lowered in the event of heavy wind conditions.
(5) Up to a five year outdoor weather-ability of fabric and support structure.
(6) Easy repair and replacement of system components.
(7) Curtain system must be of lowest cost to realize the desired features.

This article summarizes the highlights of UMD Textile Sciences Department's LSC technical development effort. The project evolved from first studying the lead pellet ballistic impact behavior of various fabric materials and then to designing a complete curtain support system. This work has culminated in the implementation of a LSC system demonstration project installation at the Standish Sportmen's Association (SSA) trap and skeet shooting club in East Bridgewater, MA (John Fabroski Club President). The following chronologically presents the technical results and details of this UMD LSC research and development project.

## SELECTION OF CANDIDATE FABRICS

Many generic types of textile fabric materials, textile structures and forms exist. It was first necessary to choose what types of fabrics should be evaluated; from nylon to polyester yarn materials to woven, non-woven and knitted fabric structures. Based on the above criteria and our technical experience, the UMD Textile Sciences Department research team set out to evaluate a number of potential candidate fabrics. Since it is known that nylon and polyester yarns are some of the toughest of the common textile fibers, these fabrics were first chosen for further study. Also, it was decided to evaluate knitted fabrics because they are indeed tough and can be manufactured in a pattern that does not tear through (un-ravel) should they become openly damaged.

Since there exists no test for measuring the lead pellet impact ballistic characteristics of fabrics, a simple field test was developed by the UMD team. The principle of the test involved taking 5 foot x 5 foot "model" fabric panels and mounting them in a PVC pipe frame and shooting at them with lead (shot gun) pellets from various shooting distances. In this Lead shot ballistic test, the fabric test sample is mounted on a wooden frame positioned perpendicular to or "normal" to the line of fire. This is the ZERO distance from which distance of shooting is based. These distance positions are marked on a "straight line" from the target frame at say, 70, 80, 90 and 100 yards from this ZERO target position. A picture of this test fabric set up is presented in Figure 1. Overall, the test is carried out by firing, from a sitting position, a total of five (5) shotgun shots at the center of the 5 ft. x 5 ft. target fabric. In this test a 12 gauge lead shot shell of 2 ¾" length, HDCP, 1235 (feet per second) velocity, 1 1/8” oz. lead shot, size 7 ½ shot STS12NH7 was used. This particular ammunition was chosen because it has a higher kinetic energy upon impact than the typical ammunition used at most skeet and trap shooting ranges. Therefore, any rating of fabrics by this UMD test method would be bias toward having the fabric rated to pass the test at generally higher than typical lead pellet impact intensity levels. After each of these five shot “rounds”, damage to the fabric is assessed. Fabric damage is recognized as yarn and fiber breakage, pellet holes, captured pellets at the point of pellet impact. The fabric’s performance is rated in terms of the shortest shooting distance where NO DAMAGE is observed in the lead pellet impacted fabric. Test values are presented in terms of the Per Cent of Non-Damage pellet Hits or PNDH. Table 1 presents results of some fabrics that were tested by the above procedure. Included in Table 1 are some fabrics that are presently being used for lead shot curtain applications.

**Figure 1: UMD In-Field Lead Pellet Impact and “Bounce-Back” Test for Evaluating Experimental LSC Fabrics.** (A Framed 5 foot by 5 foot Fabric Test Panel is shown)

Of interest, neither of the presently used fabrics for LSC applications, a woven vinyl/nylon screen fabric nor the Polymax® (open knit polyolefin) lead shot curtain fabrics passed this UMD LSC field test at 100 yards distance. From these and various other fabric testing experiments, some direction was established as to what textile materials and processing technology should be further examined in order to make suitable lead shot ballistic fabric materials. This information is summarized:

(a) Nylon Curtain Material (Passes UMD Ballistic test at 100 yards
(b) Hope/Global H/G 200X (PET) – Passes UMD's Ballistic test at 80 yards
(c) Nylon (Black) Curtain Material Passes UMD Ballistic test at 75 yards. This fabric is very stiff and does not "drape" well.

## Table 1: Some Fabrics Tested for Lead Shot Curtain Applications [(a)]

| Fabric (see footnotes)* | Areal Density (gms/meter$^2$) | Shooting Distance (yards) | PNDH** (%) | % Total Pellets Falling Within 2 Feet of Fabric |
|---|---|---|---|---|
| Nylon-MSHR675F | 436 | 100 | 100 | NA |
| (Knitted, Black) | | 75 | 100 | 29 |
| | | 65 | 98 | 45 |
| | | | | |
| Hope/Global 100X1(Nylon) | 203 | 100 | 100 | 34 |
| (Warp-Knit, White | | 85 | 93 | 21 |
| | | | | |
| Hope/Global 200X (PET) | 226 | 80 | 100 | 12 |
| (Warp-Knit, Gray) | | 75 | 100 | 16 |
| | | 70 | 100 | 12 |
| | | | | |
| POLYMAX® 70% screen | 175 | 100 | NA▼ | 58 |
| (Knitted, Black) | | 85 | 44 | 57 |
| | | 75 | 73 | 74 |
| | | | | |
| Nylon/vinyl Screen | 417 | 100 | 98 | 55 |
| (Woven, Green) | | 85 | 93 | 52 |
| | | 75 | 37 | 45 |

*FABRIC DESCRIPTION
Nylon-Knit Black 100% Nylon, 675F (Gehring Textiles, Garden City, NY)
H/G 100X1- Warp Knit nylon fabric. Hope Global, Inc., Cumberland, RI
H/G 200X - Warp Knit Polyester (PET) fabric. Hope Global, Inc., Cumberland, RI
POLYMAX® is a knitted, monofilament, Polyethylene Screen fabric available in several % shade screen densities. Tek-Supply, Dyersville, IA
Woven Screen – Green colored vinyl-coated, nylon yarn woven into an open mesh. Product supplied by Hammer & Sons Sign Company, Pelham, NH.

**PNDH** - - - **P**er Cent **N**on-**D**amaging **H**its by the impacting lead shot pellets.

NA▼ - - refers to the fact that the pores or openings in this fabric were so large, that at 100 yards, many of the lead pellets (nominally, 2.4 mm diameter) passed through the fabric without damaging the filaments. However, at 85 and 75 yards, broken and distorted filaments were observed.

From these data, a decision was made to pursue the development of Lead Shot Curtain fabrics made using the warp-knit process and having an areal density of (nominally) between 100 and 400 grams per square meter. Of significance, the warp-knit process is a most versatile of all textile processes. Fabrics can be manufactured in widths up to 200 inches using the warp-knit process. Following this and the results of Table 1, it was decided that polyester (PET) based yarns would be used as the fiber material. The rational for using PET is based on the fact that PET yarns are the most mechanically and environmentally durable among the common textile fiber/yarn materials. PET yarns are also of relatively low cost. As a result of numerous warp-knit fabric development trials, a polyester based, "80-yard fabric" has evolved and was chosen for further field demonstration testing. This fabric has been assigned the trade name XXXXX™ 80 to convey the fact that the fabric can block lead pellets from landing into unwanted areas. XXXXX™ 80 has been shown not to be damaged by shotgun dispensed lead pellets from a distance of 80 yards from the shooter. In fall 2004, actual shooting range-field tests were carried out on a large sized curtain assembly (20 foot x 34 feet) at the Standish Sportsman's Association range. The fabric showed no damage after multiple rounds of lead shot (skeet range) at an 80 yard distance. In this trial, while the fabric performed very well, the curtain size was found to be too large to be conveniently handled and supported. From this experience, it was decided that narrower curtain widths should be submitted for shooting range field evaluations.

In addition to blocking lead pellets, the use of lead shot curtains at shotgun shooting ranges should offer a means of facilitating the recovery and recycling of lead shot. Appropriately positioned lead shot barrier/curtains can serve to confine the field areas where the spent lead shot can land thereby lessening the exposed land area required for lead shot recovery. At some existing shooting ranges, a large ground fabric is positioned on the ground in front of the lead shot barrier curtains to catch the fallen lead pellet. In other instances, sand or gravel beds have been placed in the vicinity of the barrier curtains. These lead shot capture systems require the lead pellets to be collected from the "geo-textile" fabric mat or else sifted out of the sand or gravel. If barrier curtains and on-the-ground capture matt design areas can be developed that are able to confine the spent lead shot to a smaller "contaminated" area, the ease of any recovery/clean-up/recycling effort could be greatly reduced. Table 1 presents data on the "bounce back" characteristics of the various fabrics tested. Here, during the test, a ground area up to eight feet in front of the 5' x 5' test curtain (Figure 1) was first covered with a white "blanket" of non-woven fabric. After shooting 5 rounds for the test, the total number of pellets that bounced back from the fabric upon impact is counted. The data in Table 1 presents the percent of the total number of bounce back pellets that fell within two feet in front of the impacted fabric curtain. Qualitatively, at least, the higher percentage of pellets that fall within two feet of the curtain, the better this fabric is in containing the ricochet of the pellets once they hit the fabric target. While some fabrics might be better than others, it was noticed that this bounce back value also depends on the drape qualities and physical tension put on the fabric test curtain panel mounting during the test; the more drape in the fabric and the lower the mounting tension, the shorter the pellets would bounce back away from the front of the curtain surface. On the other hand, the further the lead pellets bounce back off the curtain fabric, the less kinetic (impact) energy if absorbed by the fabric. The characteristics of pellet bounce-back, lead pellet capture and recovery are the subjects of future UMD research and development studies.

## SUPPORT SYSTEMS FOR LEAD SHOT CURTAINS

While the development of ballistically durable fabrics for LSC applications is pivotal to this research, another important issue is the actual structures that can be used to support these developed fabric curtains. As a preview to our study of the LSC support structures, during the fall of 2003, several gun clubs were visited by UMD personnel. Here we learned about what has already been done at several gun clubs concerning LSC curtain installations. These gun club site visits provided some very useful insights to the technical needs of Lead Shot Barrier Curtain systems and structures. At one club, an installation of 19 telephone poles, spaced 8 feet apart, approximately 80 yards from the trap field firing line was observed. The total spread of this installation was about 144 feet. The pole length above the ground was 60 feet. Here, a 5 foot wide section of Green Woven Screen fabric (see Table 1)[available from Hammar & Sons Sign Company, Pelham, NH] was hung, 2 feet from the top of each pole, to span across the 19 poles. Two additional rows of 5 foot wide Woven Screen fabric were hung below this initial top section. These fabric panels were secured to the poles by 1 x 5 pine boards nailed to the poles. The total length (top to bottom) of the Lead Shot Curtain was 15 feet. All three sections of fabric were supported by 1/4" steel cable. This prevented sagging of the fabric sections between the poles. This was a somewhat permanent installation that was poorly maintained. The fabric showed extreme damage by the lead pellets indicating the poor performance of the woven vinyl/nylon screen fabric. This fabric is a vinyl coated nylon filament yarn, fine mesh (screen-like) woven structure whose mesh has been heat fused together to make a drape-able curtain. Unfortunately, neither vinyl nor nylon is very resistant to long term UV exposure and weathering. Also, vinyl coatings do not have a good abrasion resistance. At this club, this green colored woven screen fabric has been replaced and/or patched-up several times during the past 3 years. The appearance of this particular LSC installation was very poor. Nevertheless, this installation is applauded for its effort to prevent lead contamination of the surrounding soil.

At another gun club, 11 telephone poles were installed 50 feet above the surface (buried 5 feet deep). These poles were in a row placed 20 feet apart and 105 yards back from a trap station firing line. 20 foot wide, 34 foot long sections of barrier curtain were prepared from the same woven vinyl/nylon screen fabric material that was used at the previous club. These fabricated fabric panels were supported at the top with 20+ foot lengths of 1 ¼ inch black iron pipe and at the bottom with 1 ¼ inch PVC pipe. These 20 foot wide panels were then hung between the poles starting at 2 ½ feet from the top of each pole and extending 34 feet downward. This curtain assembly was not secured at the bottom; the curtain was allowed to drape and swing somewhat freely at the bottom. With less tension on the fabric, this served to make the curtain fabric more impact resistant. Of interest, a cable and pulley arrangement was attached to each 20 foot wide (iron pipe boom) section between the poles so the curtain could be easily lowered in case of very high winds or else if maintenance of the curtain was needed. A zone of rocks and gravel was deposited in front of this curtain to serve as a lead shot drop area. It was not clear when and how the lead shot would be removed from this rock/gravel mixture. Here also, the green woven vinyl/nylon screen curtain fabric material was observed not to be holding up too well to the barrage of lead shot pellet impacts and the 2 years of outdoor weathering. Replacement of the fabric at this club was pending. However, the functional service of this particular lead shot curtain installation was, overall, much better than the previously described installation. This gun club should also be commended for its environmental protection efforts. Overall, the fact that fewer poles are used and this system had the feature of the facile raising and lowering of the 20 foot wide curtain panels indicates that the design was well thought out. In view of this learning experience, plans were developed to design a UMD experimental lead shot barrier curtain system. This was done in consideration of the previously outlined criteria in a previous section of this review article.

**(1) Positioning of Lead Shot Curtains and Support Structures**

Presently the use of strategically positioned lead shot barrier curtains are considered to be the best immediate solution to the lead shot environmental migration issue. The location of a curtain barrier system on a particular shooting range is very important. However, it is difficult to determine this from first principles of physics and engineering. This is based on the realization that calculating the projectile dynamics of lead shot blasted from a shot-gun is not straight forward. A shotgun blast does not involve the ejection of a single projectile. Multiple (lead pellet) projectiles are involved. Therefore, multiple intra-pellet collisions occur during a shot gun blast making calculations very difficult. However, some generalizations have been established. For example, the projectile patterns at a typical trap shooting range and theoretical shot-fall zone are diagramed in Figure 2. As shown, the pellet shot fall pattern spreads out after about 100 yards from the shooting position.

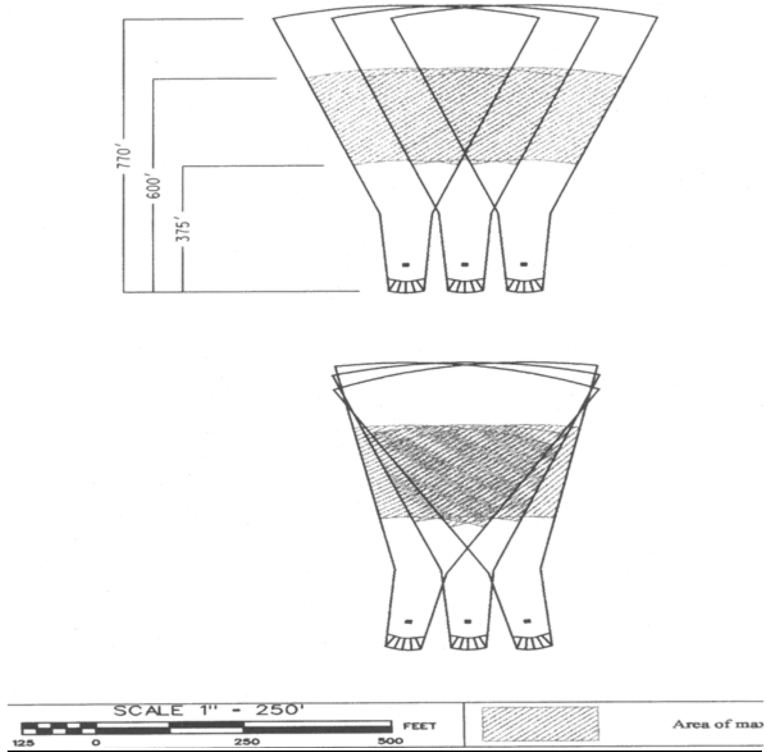



**Figure 2. Theoretical shortfall zone and maximum shot-fall at trap fields.** The cross-hatched area indicates maximum shot-fall zone. [National Shooting Sports Foundation, Facility Development Division, "Environmental Aspects of Construction and Management of Outdoor Shooting Ranges, NSSF, Newtown, CT (1997)]

This gives one a measure of how wide the curtain assembly should be spread across the protection area in a typical trap field setting. Another important parameter is how high the curtain should be positioned above the trap field, and of course, how long the curtain should drape down. It has been found the most effective way of determining the height and length of lead shot curtains is to determine these parameters from "trial and error" methods. Data are available from the various gun clubs who have observed the pattern/location of lead pellet impact from their experience. From this, some general distance and curtain barrier area dimensions have been empirically established. For example, at a trap shooting range needing to block pellets at 80 yards from the shooter, the LSC fabric should be placed at a top height of 50 feet above the ground and drape down to 16 feet above the ground. Therefore a 34 foot long fabric curtain system will be needed for this particular trap shooting range. For ranges with shorter shooting distances, narrower curtains will be needed; for longer shooting distances, wider and longer (top to bottom) curtains will be required. Finally it must be stated that the exact positioning of the LSC system at a shooting range will always depend upon the terrain topography of the particular range and also what parts of the range must be most effectively protected from lead shot contamination. In other words, the positioning of the LSC barrier structures will always be unique to the particular shooting range being "fitted" for a LSC system.

**(2) Specifications for LSC Support Structures**

With the relevant positioning of the curtain structure is of initial concern, there are longevity concerns. Since the curtain and structure is subjected to the pelting of shot, sunlight, wind and other weathering factors, the curtain will have to be replaced in a few years. Other clubs that may be interested in erecting a shot capture curtain are also concerned about the durability and overall life span of the curtain and support structure to insure a cost-effective lead shot management program.

From our research and field studies some performance criteria have been proposed for Lead Shot Capture Systems. These are listed below:

- Fabric should be damage resistant to impact by multiple rounds of lead shot pellets shot at a specified distance.
- Fabric and support system should have a five-year outdoor weather-ability.
- Fabric should have a minimum "bounce back" of pellets upon impact.
- Fabric material and support system should have a low wind-drag coefficient.
- Fabric barrier system should be easily deployed, easily repaired.
- Fabric support system should allow for the easy lowering or furling of the fabric curtains in impending high wind and/or severe weather conditions.
- The system should be of a low cost/performance ratio.
- The complete system should have a respectable appearance

**(3) Standish Sportsmen's Association (SSA) Demonstration Installation**

Late in 2004, a "Demonstration Project" was initiated at the Standish Sportsmen's Association (SSA) Club, East Bridgewater, MA. Here, UMD agreed to help this club set up an experimental LSC system by supplying them with the needed LSC assemblies. Having established the above criteria, a number of curtain support system arrangements have evolved. From our own ideas and suggestions derived from reviewing existing installations, it was concluded that the most prominent curtain system involves the setting up of 50 to 60 foot high (out of the ground) poles set 20 feet apart across the back section of the shooting field. The curtain/pole installation distance from the shooter it determined by the barrier protection limits of the particular LSC fabric. For XXXXX™ 80, this would be 80 yards. In this demonstration project, SSA agreed to install eleven poles at their site and affix them with support and mounting cables, pulleys and tethering lines. To the top section of these poles was fixed a set of two cables- - - - one cable cantilevered out 12” to 18” in front of the pole and the other cable cantilevered out 12” to 18” away from the back of the pole. This arrangement was designed so that curtains could be hung onto this “continuous” double cable without concern for the distance between the poles. Here, UMD was responsible for supplying SSA with the 20 (twenty) curtains for mounting onto this pole and cable assembly.

XXXXX™-80 LSC fabric is supplied by Hope Global, Inc. Cumberland, RI in 8 ½ foot widths. Therefore curtains were sewn having the dimensions of 8½ foot wide by 34 feet long. This curtain length was determined by some preliminary shot fall studies (Figure 2) and dictated by the particular dimensional needs of the SSA site. From these dimensions, a curtain fabric assembly was then prepared. This is diagramed in Figure 3. This curtain features a top boom consisting of 1 ½ “ diameter galvanized steel conduit pipe. This top boom was inserted into the 6” wide hem at the top of the curtain. Another boom, a 1 3/8” diameter galvanized top rail fence pipe, is inserted into the 6” hem located at the bottom of the curtain. In order to steady the shape of the curtain under windy conditions, two “battens” were placed at the (approximate) one-third positions along the 34 foot “drape” length of the curtain. Attachment clamps were then affixed to each end and in the middle of each boom. This attachment hardware also served to secure the curtain to the booms.

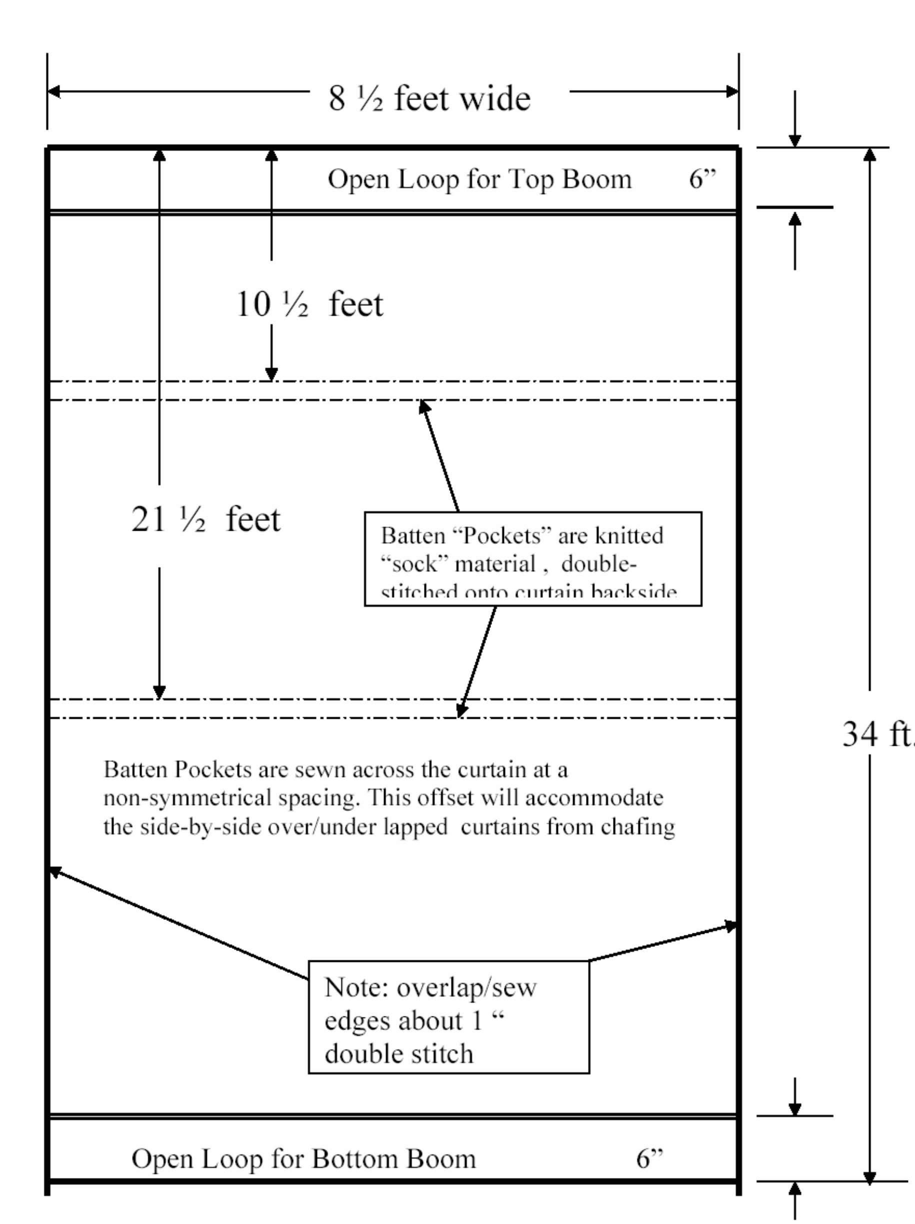



**Figure 3: XXXXX™ 80 Fabric Curtain Design and Dimensions -"Standish" Model** (not to scale)

Mounting these curtain assemblies to the SSA support system involves securing them with rope and pulley fixtures, to the double cable system fixed (and off-set) at the top of the poles.

To alleviate the effect of unexpected wind stresses, the Standish Sportsman's Association Club, (Mr. John Fabroski and the club members) have come up with the idea of fitting each individual curtain with a double row of cable lines such that the curtains would be able to be folded up on itself. This requires the top boom of the curtain to be permanently fixed to the top cables of the support system. Now, to collapse the curtain, one has to only pull on the rope line attached through the grommeted lines that were fitted through the curtain face. The curtain would then fold up upon itself and finally be stored in a “bundle” at the top of the support poles and cross cable. Part of this SSA LSC fold-up curtain installation is pictured in Figure 4. It represents a LSC support structure installation arrived at by the joint cooperation between UMD and SSA’s President, John Fabroski and his club members. The SSA group continues to carry out experimental studies on their LSC support system.

**Figure 4: Photograph of Lead Shot Curtain Structure at the Standish Sportsman’s Association Range, East Bridgewater, MA**

The general rule for this described LSC installation, as stated by SSA members, should be “if in doubt, take down or fold up the curtains” after each shoot. Overall, the subject SSA installation is performing as intended. It is blocking lead pellets from falling into unwanted land areas. The performance of this demonstration installation will continue to be monitored.

**(4) Some Additional LSC Support Systems Suggested by UMass Dartmouth**

An important consideration in the design of LSC support systems is the use of a truss structure across the tops of the poles. Truss structures are widely used in the field of overhead highway traffic and directional signs. In LSC systems, a truss structure across the top of the poles is recommended over the double cable set-up as described in the Standish Sportsmen’s Association installation. Overall, the truss structure will help distribute the stress across the series of poles and will enable the curtains to be hung without sagging which is prominent in the cable-across-the-pole-top method described (see Figure 4). It is recommended also that the poles be appropriately guyed to ensure their stability under wind load stresses. A sketch of the truss structure across the tops of the poles is shown in Figure 5. Here, a box truss structure is shown. The use of a box truss allows for the curtains to be mounted in different ways.

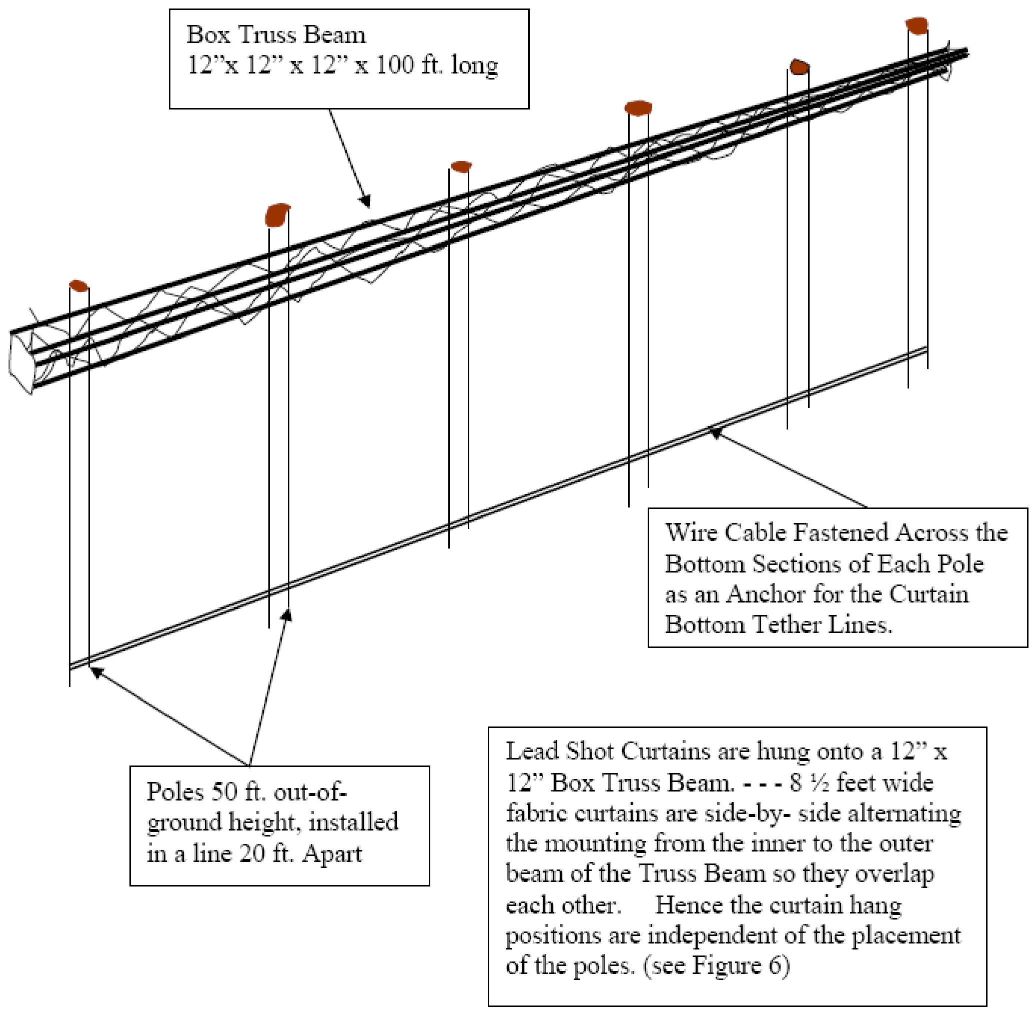



**Figure 5: Box Truss Structure Positioned at Top of LSC Support Poles. Poles must be properly guyed**

One configuration involves mounting the curtains in a more or less straight overlap as shown in Figure 6 (top picture). Another more preferred configuration is having the LSCs mounted in a louvered mode (bottom picture) also shown in Figure 6.

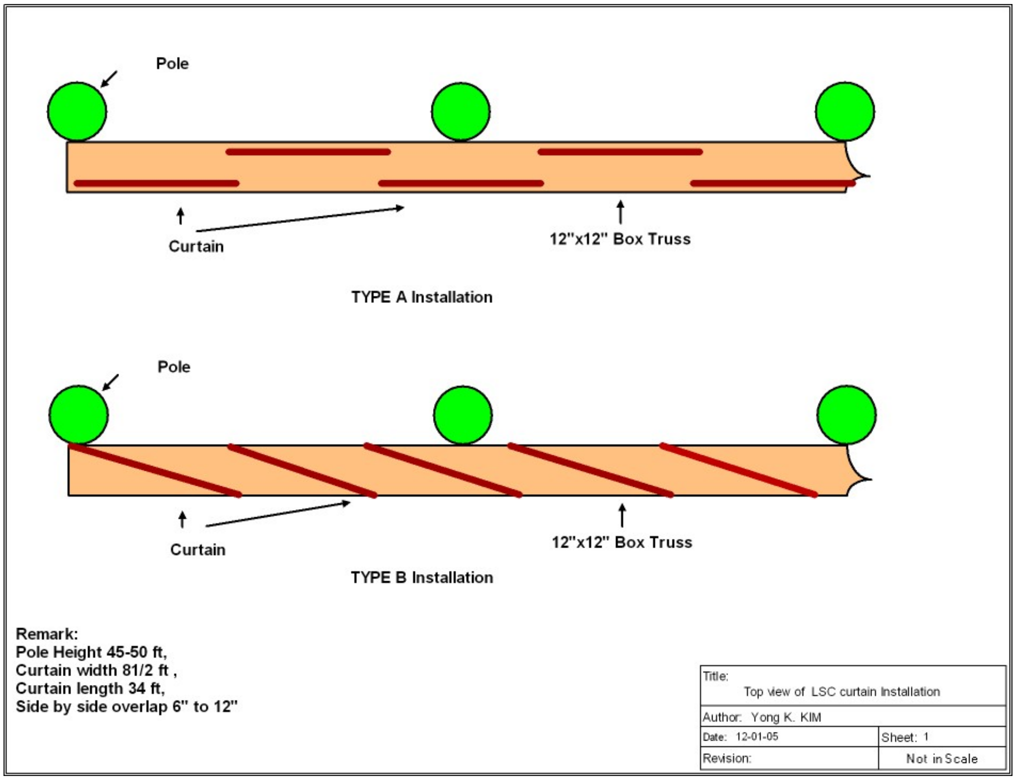



**Figure 6: Top View of Different LSC Hanging Installation Modes (Type A – Straight Overlap, Type B – Louvered Overlap)**

Three 8 ½ foot wide curtain assemblies can be positioned, in a "louvered" configuration, between each 20 foot wide spacing between the poles. The louver top width should be between 18" and 24" in width to allow for enough open louver. One end of the top boom is secured to the front cable or Box Truss structure and the other end is secured to the back cable or back of the Box Truss structure. If a box truss structure is used, a back cable offset structure must be installed to fix the other end (or side) of the curtain to keep the curtain's left and right sides 18" to 24" away from each other. This louvered curtain arrangement is sketched in Figure 7. This positioning allows for each curtain (with battens) to over/under-lap each other with enough space between each curtain for the wind to flow through. Most importantly, this louvered assembly can serve to help reduce wind loads on the curtain when the wind is coming in the open direction toward the

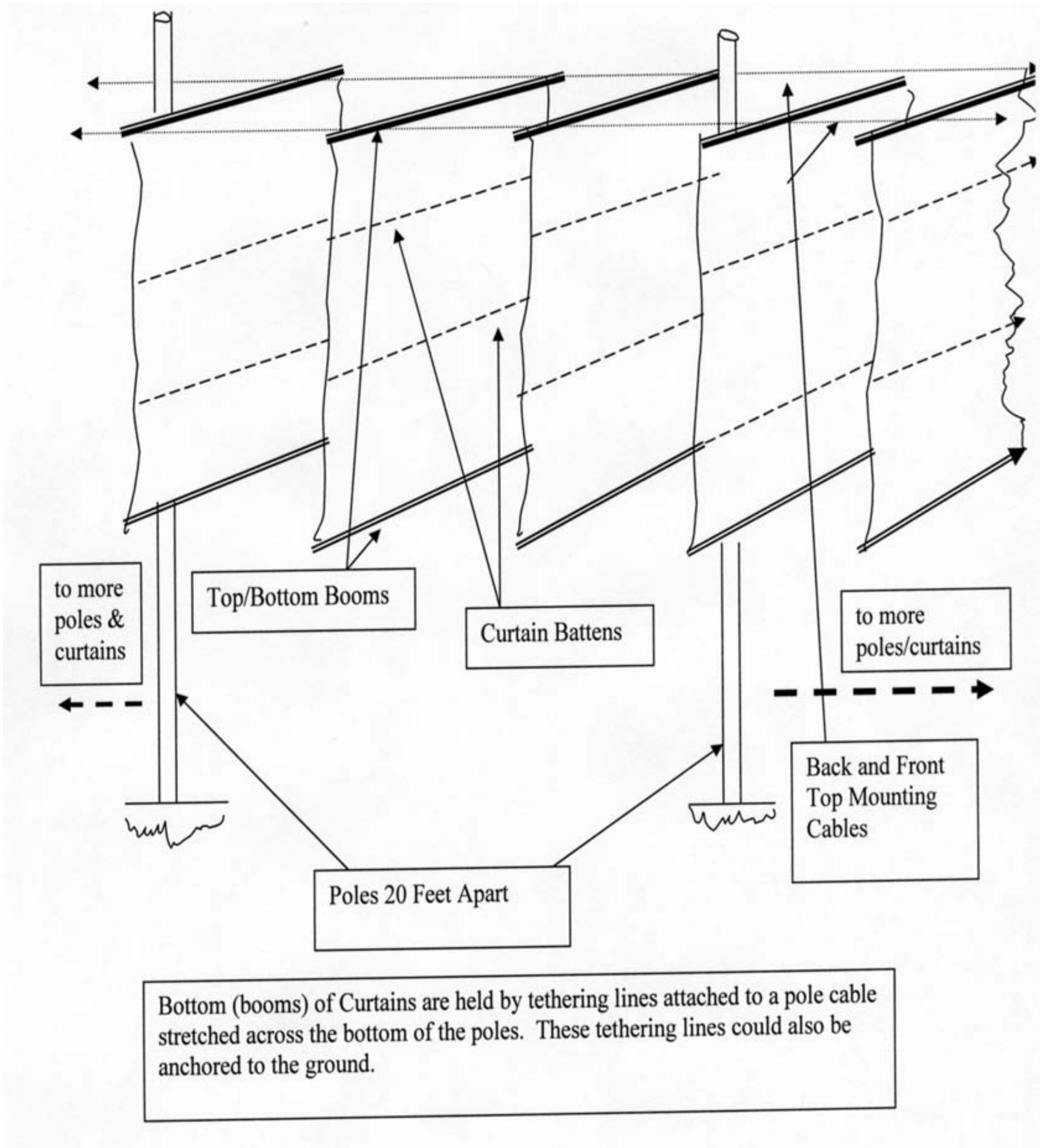



**Figure 7: Sketch of Lead Shot Curtain- Louver Design (not to scale). (Note: Cable across bottom section of poles to hold tethering lines not shown in this diagram-refer to Figure 5).**

open slots of the louver. In such installations, the "louver direction" must be selected so as to accommodate the direction of the passing prevailing winds. Another feature that can be implemented with this design is the installation of elastic (bungee cord) tethering lines on the bottom of each curtain. This feature can be installed in order to protect the LSC system from being damaged by unexpected wind bursts. Here, as the force of the wind increases, the bottom-of-curtain tether lines would stretch, allowing the curtain to "bend away" from the wind at the bottom and therefore relieve some of the wind force on the complete LSC structure. This feature is still in the experimental development stage. The fine details of this design are still evolving. Since this LSC support structure design has the facility to raise and lower each 8 ½ foot wide curtain individually, it is recommended that the curtain be lowered when the curtain is not in use. As it has already been experienced with this SSA installation, damage to the curtains and its support structure can occur if it is struck by rogue, intense (say 40 to 50 mph or higher) wind gusts.

**(5) Draw-Drape Curtain Design Developed by the Standish Sportsmen's Association**

All the previous LSC support structure designs are meant to be used more or less as permanently deployed, all-weather curtain systems. The idea is that these curtains are to be left up and only lowered in impending wind storms and in foul weather like in winter. As an alternative to this design, a simple and clever draw-drape curtain structure was conceived and implemented by SSA gun club personnel . SAS wanted a curtain support structure that could be opened and closed (secured) after every shooting session. They patterned their operating design after the opening and closing of window draperies. A diagram of the Standish Draw-Drape LSC curtain design is presented in Figures 8 and 9. Here 8 ½ by 34 foot curtains are held onto the cable at the top of the support poles by a grommet and ring assembly. The curtains are positioned in groups of four (4) such that these four curtains span across three side-by-side erected poles (twenty feet apart). Each curtain overlaps the other by about 12 inches. Carriage bolts and washers are secured into the double grommets at the slides of the curtain (see Figure 8) to hold the overlapped curtains together in the wind while they are deployed. The two middle curtains are not fastened together in the middle of this four-curtain assembly. The middle pole of the three support pole array serves as the center of this four-curtain assembly. This "middle" pole serves as the center point for the Draw-Drape assembly. A diagram of the line and pulley arrangement illustrates how the curtains are opened and closed in a Draw-String like manner. The simplicity of this LSC opening and closing system is shown. Pulling on the middle rope (Blue in Figure 9) will draw both the left and right hand sides of the curtain assembly together. The offset pulley positions allow for these center curtains to overlap. One person pulling on this middle (Blue) rope deploys the four curtains. Alternatively, the curtain can be secured (removed from it's lead shot barrier function) by pulling on each of the side ropes. Pulling on these ropes will draw the curtains nest to the side poles. Once the curtains are drawn against these side poles (#1 or #3), the curtains can be wrapped around the poles with the ropes tied or cleated to the pole for a secure storage of the curtains. Figure 10 is a photograph of the deployed Standish Draw-Drape LSC system. The Standish Sportsmen's Association personnel are very comfortable with this arrangement. They find no objections in their having to open and close the LSCs before and after each shooting session. This Draw-Drape arrangement is working out very well for their needs. Also important is the fact that the curtain system has already withstood some relatively heavy weather in its secured condition. Importantly, this Draw-Drape design also appears to be a low cost approach to a uniquely functional LSC support system.

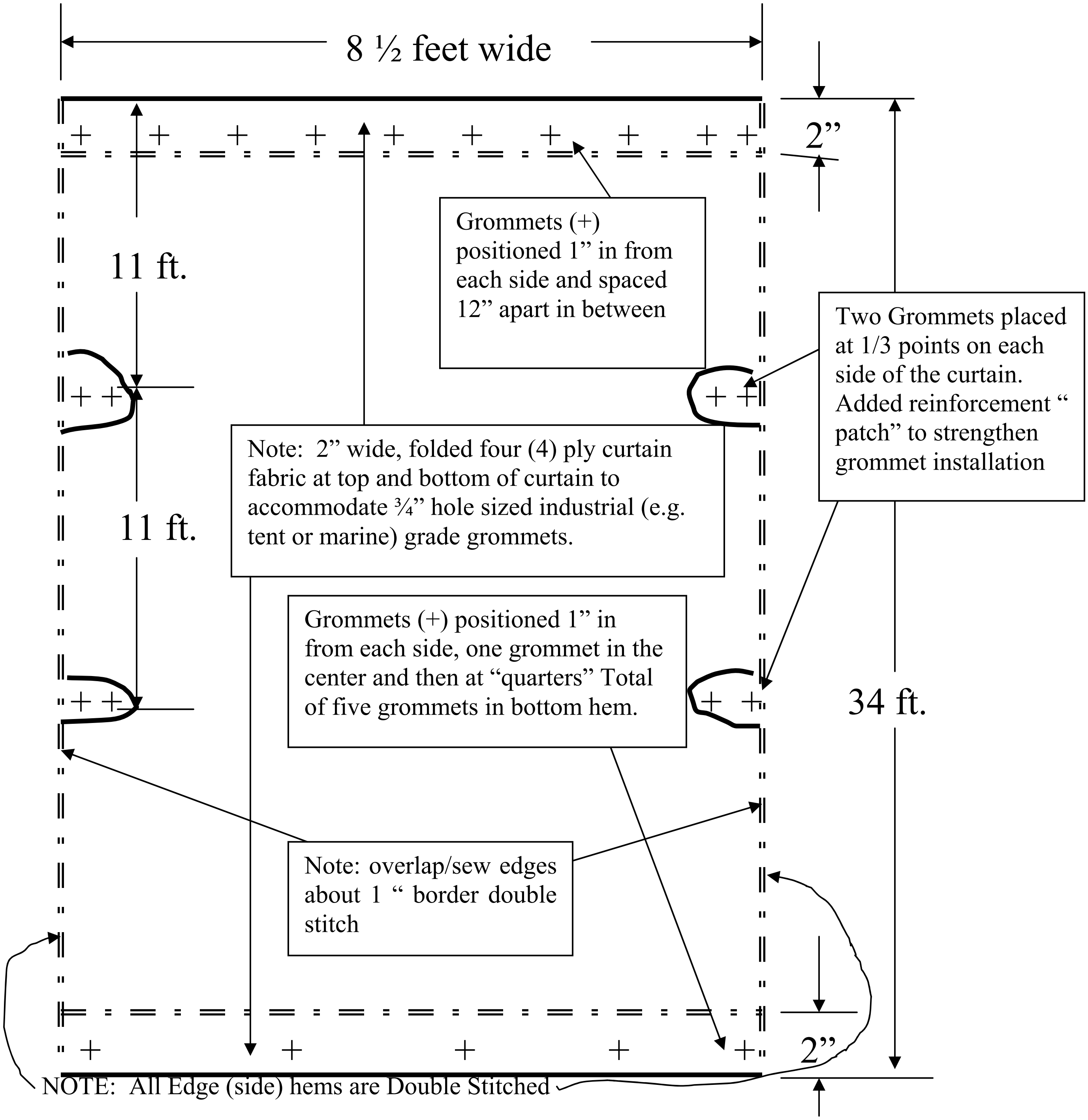
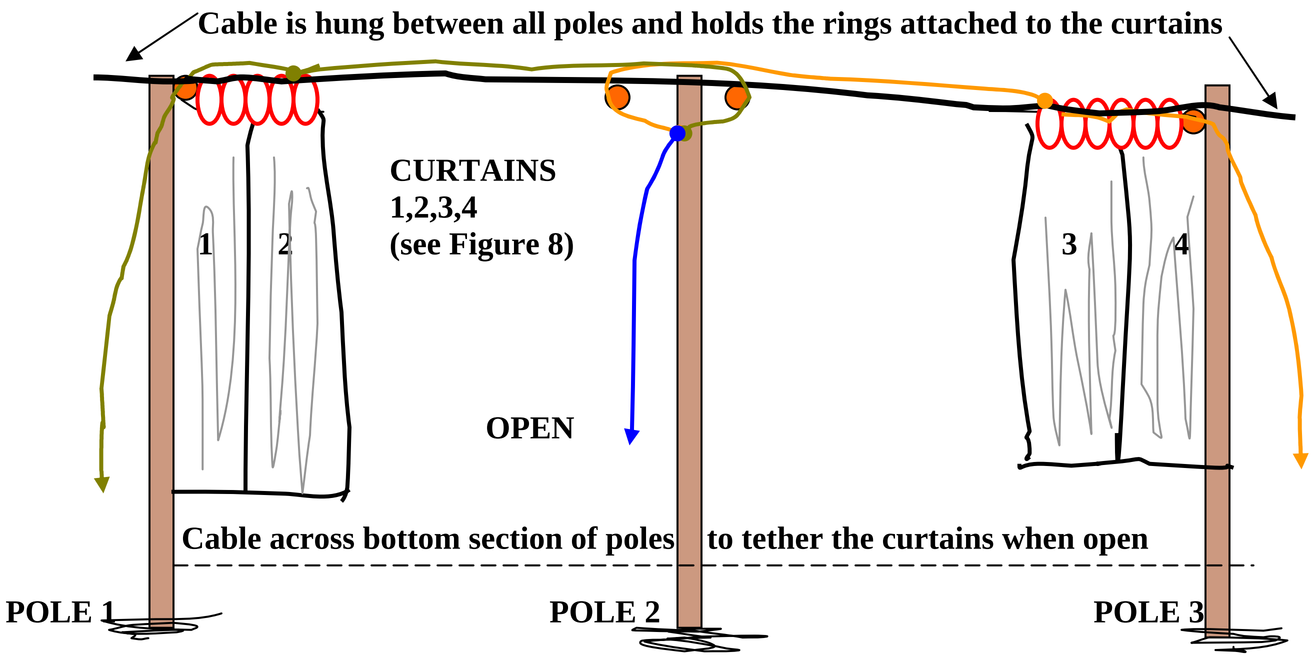



**Figure 8: “Draw-Drape” LSC Design developed by the Standish Sportmen’s Association Gun Club - - 8 1/2 foot by 34 foot (not to scale)**




= 2 ½ inch single pulleys with no swivel

= Rings attach top of curtains to cable so they slide across Top Cable

= Pulling down on this rope will draw the curtain toward center Pole 2
Deploying the curtain. Rope pulls all curtains toward center.

Left securing = Rope pulls curtains 1 and 2 to Pole 1. The curtains
are then wrapped and secured against Pole 1.

Right securing = Rope pulls curtains 3 and 4 to Pole 3. The curtains
are then wrapped and secured against Pole 3.

NOTE: The connecting ropes at the middle Pole top are offset so that
when curtain is deployed, the curtains will overlap)

**Figure 9: Diagram of the Draw-Drape Curtain Opening and Closing Rope and Pulley Arrangement. (not to scale)**

**Figure 10: Photograph of Draw-Drape LSC Design Developed by the Standish Sportsmen's Association; LSC Deployed at SSA, East Bridgewater, MA**

### 6. Double Curtain, Experimental Lead Pellet Capture System

A UMD designed Lead Pellet capture system is in its development stage. The system involves placing a relatively open-net, knitted mesh fabric in front of the LSC barrier fabric in a dual fabric configuration. The "front" fabric has an open net structure that has open and loose mesh openings that are slightly smaller than the diameter of the lead pellets. In this double curtain arrangement, this first fabric layer allows the lead pellets to pass through the fabric, thereby causing them to loose much of their kinetic energy. The pellets then proceed to strike the back barrier fabric to dissipate the rest of their kinetic energy. These "spent" lead pellets then fall, by gravity, through the space between the two curtains and into a capture bin or trough placed at the base of these two curtains. A sketch of this experimental lead capture system is presented in Figure 11. To test out the idea illustrated in Figure 11, UMD has constructed an experimental modular double-curtain support structure. The size of this double curtain assembly was about 8 ½ feet wide and 7 feet long. The top of this curtain assembly was positioned to be 10 feet above the ground. To carry out important field-testing, this constructed test module transported to and set up at the Standish Sportsmen's Association range. A photograph of this installation is presented in Figure 12. Here tests were carried out where the 8½ foot by 7 foot double curtain were shot at from a distance of 80 yards. In these tests, the double curtain lead pellet capture concept was successfully demonstrated- - -from the 80 yard shooting distance, over 50% of the lead pellets that were shot were captured in collection bin. All the pellets that struck the front of the 8 ½ by 7 foot area curtain were captured. It is projected that if the area of the curtain were larger, 100% of the shot pellets would be captured. Experiments on this double curtain, lead capture barrier system concept will be continued. A full scale double curtain system experiment is being planned by the Standish Sportsmen's Association.

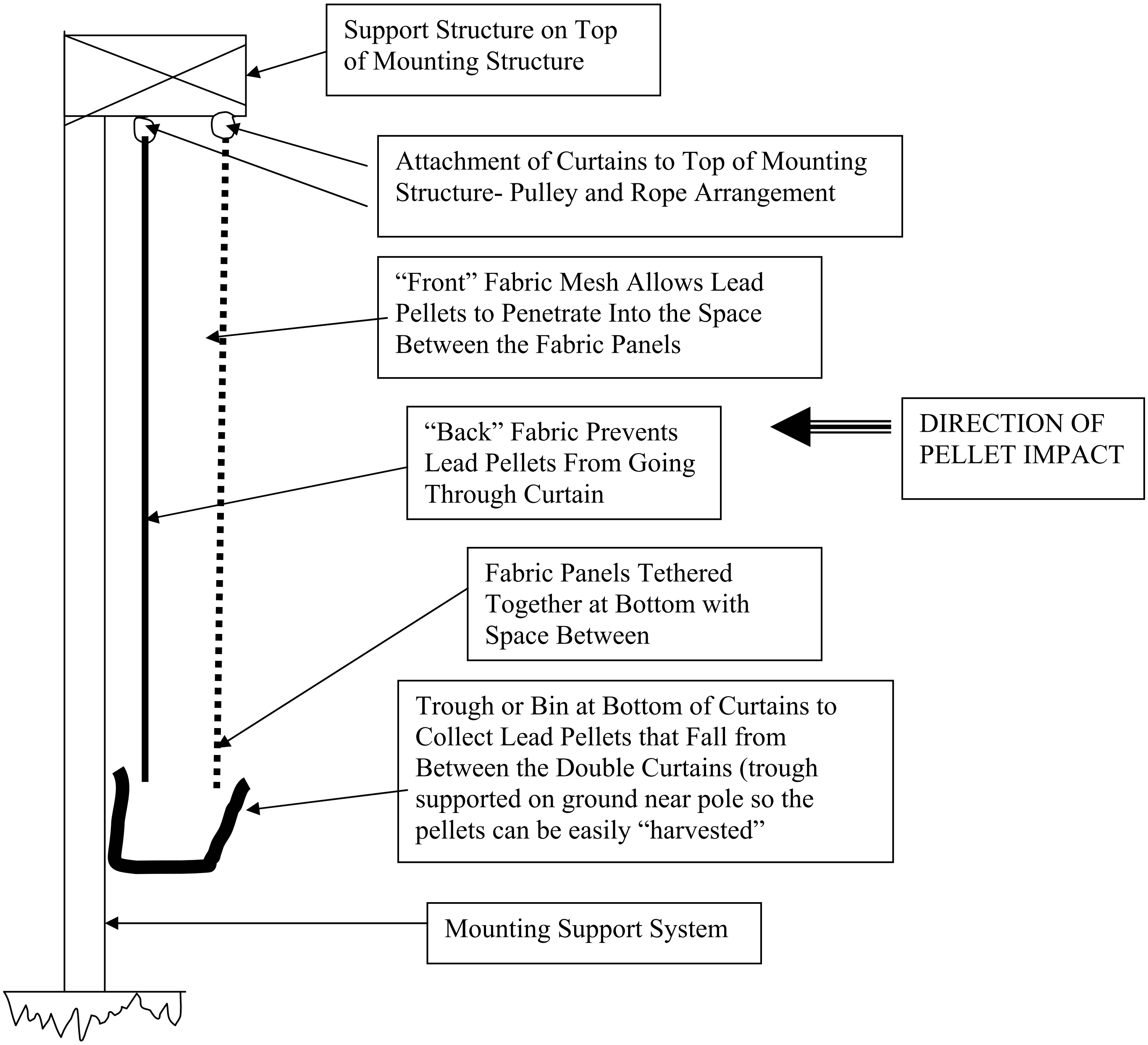



**Figure 11: Diagram of Double Layer Lead Shot Barrier Curtain Configuration**
(Side view, not to scale) Note: The diagram shows the curtains are hung with a space between the two curtains. This space could be varied. For example, we have tested panels with a space of 12" at the top and 2" at the bottom.

**Figure 12: Photograph of Double Curtain Modular –Lead Pellet Capture System Located at the Standish Sportsmen's Association Range.**

## FUTURE CONCEPTS AND CONSIDERATIONS

As the progress and UMD's LSC developments are herein reported, several important aspects of this technology are worthy of further development and should be pursued. Some of these are:

(1) Fabrics capable of successfully blocking lead pellets at less than 80 yards.
(2) Double curtain designs that can effectively capture and recover the impacting lead pellets should be optimized.
(3) Structural support systems that will withstand higher wind loads so that the LSC system can be kept hoisted semi-permanently an kept deployed at higher wind loading conditions.
(4) Moveable, modular curtain mounting systems (as in Figure 12) that will enable LSCs to be placed (and easily relocated if necessary) at strategic locations at the shooting range.

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