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Lancework — Pictures in Fire

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ABSTRACT

Lancework set pieces can be one of the most interesting forms of fireworks. If one uses high-quality lance formulas, skillfully designed lance figures, provides clever animation, or tells an interesting story, the entertainment value of lancework can reach the heights it should. This article describes the methods used by the authors to design, construct and display lancework set pieces. There are also short appendices written by C. Jennings-White, M. VanTiel, and R. Winokur, wherein they present their views on some points relating to this article.

Introduction

Lancework set pieces can be one of the most interesting forms of fireworks, especially if they are animated or otherwise engage the audience. Most audiences have seen an American Flag, "WELCOME", or a company name or logo at a fireworks show. These set pieces generally burn for about a minute, and that's a long time to look at the same thing. However, when they are looking at a set piece and then it moves, a delightful reaction is heard, and that is what fireworks displays are all about — entertaining the audience.

In addition to their entertainment value, there are other reasons to consider including more elaborate lancework in fireworks displays. The recently revised National Fire Protection Association (NFPA) separation distance requirements may significantly limit the size of aerial shells that can be used in many fireworks displays. Thus smaller fireworks sites may have to rely more heavily on ground displays. In addition, ground displays can be used to refresh the spatial perspective of the audience. Normally, during the performance of a display, ever larger shells or more rapid firing are required to maintain the entertainment level. For example, immediately after displaying a magnificent six-inch, color-changing chrysanthemum, the appearance of a three or four-inch shell (or even a five-inch shell) may not be very impressive. However, if the display operator interrupts the aerial display and presents an interesting set piece, then that same three or four-inch aerial shell will be much better received. When it is possible to use this method of improving the perceived appearance of smaller aerial shells, the entertainment value of the display can be increased at no additional cost.

The methods described in this article are those used by the authors during a period in the early and mid 1980's when they performed fireworks displays. These methods produced good results; other methods that were tried were less successful. However, it is not intended to imply that these methods are the best or only methods that will produce good results.

There are three short appendices at the conclusion of this article. These were written by C. Jennings-White, M. VanTiel and R. Winokur, and they present their views on some points relating to this article.

Lancework Design and Frame Construction

Where does one start to design a lancework set piece? First, the basic idea must be formulated; for example, a skit in which a military tank is one of the players. The next step is to sketch the tank design. It should be as simple as possible. People only need enough detail to identify the item; their mind's eye will fill in the rest. For example, there is no need for drive and idler wheels, just outline of the main elements that make it a tank: the track, turret, and gun barrel (see Figure 1, top). Too much detail may make the design less recognizable and will require more lance tubes. This will add to the cost and certainly will produce more smoke, which can detract from the appearance of the set piece, especially with an unfavorable wind. Finally, in considering various tank designs, consider how it is to be perceived. If it is a comic skit, the tank

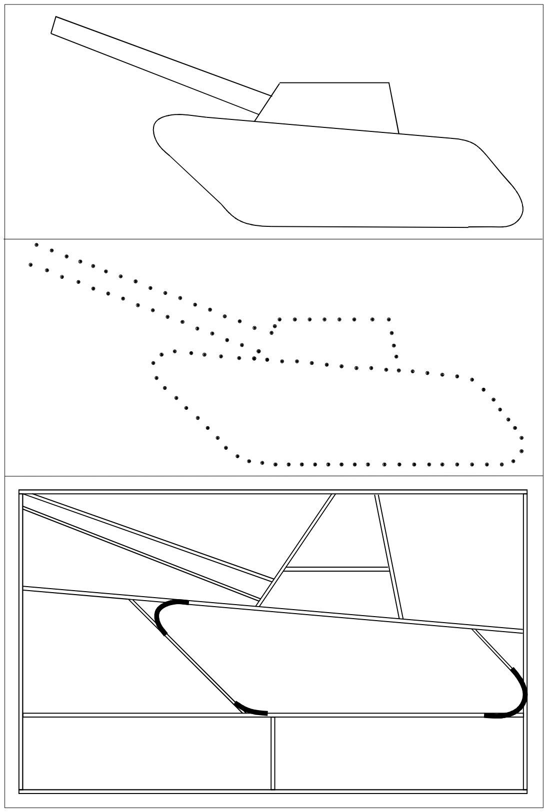

Figure 1. (Top) Sketch of a tank design for a lancework set piece. (Middle) "Dots Only" view of how set piece will appear as a burning lancework. (Bottom) Sketch of lance frame showing frame members and rattan segments.

should not appear menacing; so shorten the gun barrel and increase the height of the track and turret. If it is supposed to be racing forward, increase the forward angle on the track.

Once pleased with the basic sketch, transfer it onto and 8 ½ × 11-inch sheet of paper to check out how it will appear as a lancework. Using something like a broad-pointed, felt tip pen, make fairly "fat" dots, about ½-inch apart around the sketch. Start by placing dots at the end of each line segment (at each corner or where there are sharp changes in direction); then, fill in the rest of the dots. If a pen that readily "bleeds" through the paper is used (e.g., a "Sharpie" pen by Sanford), the paper can be turned over to see only the dots, and not the lines from the drawing (see Figure 1, middle). Such a "dots only" view is how the design will actually appear and should be used to evaluate the design. Observe the drawing at a distance of about six to eight feet. If the mind's eye can still clearly see what was in your sketch, the design is headed in the right direction. It may take several tries before settling on a design and dot pattern that is clearly recognizable and has the appearance being sought. Sometimes it is necessary to add some "helper" dots, these are dots placed closer than the normal spacing to make sure that the eye follows the intended outline (e.g., in Figure 1 (middle) where the gun barrel meets the turret). For the same reason, it is often helpful to slightly decrease spacing around bends, especially tight bends. In other areas the spacing will need adjusting so that after a dot is placed at each corner, and the dots filling the remaining space are roughly equidistant from each other. Once the necessary adjustments have been made, ask someone else what they see when viewing the drawing from about eight feet away. If it is obviously a tank and gives the desired impression (comic, menacing, fast moving, etc.), it is time to construct the lance frame.

A well-designed lancework set piece, one that is animated or part of a skit telling an interesting story, should be well received in many different venues, and even if repeated at the same location after a few years. Thus, set pieces should be made sturdy enough to be reusable. This requires some additional effort to strengthen and maintain the lance frames, but it represents a substantial cost savings over a span of only a few years. The authors' standard frames were six by ten feet as this was the size of the trailer used to transport the lancework set pieces (more on this later). For larger set pieces, multiple panels would be joined on site. Occasionally, smaller frames were used, but they were always made six feet long to span the mounting rails in the trailer.

To design the lance frame, start with the basic sketch of the figure to be portrayed, and draw the frame boundary (e.g., 6 × 10 feet). Next, identify all straight lines of the design and extend them to meet the frame or until they meet another straight line segment. These lines correspond to what will become a wooden member of the lance frame. Since it is necessary to have cross bracing in a lance frame, when practical, that cross bracing should be placed to correspond with parts of the design. This makes the strongest frame for the least weight (see Figure 1, bottom). It may be necessary to include some additional lines (frame members) where more strength is needed. Next, indicate on the frame where rattan will be needed for curved sections (shown as solid bold lines in Figure 1, bottom). When there are few if any straight line segments in the design, place the bracing so that the rattan is supported about every 18 inches, but avoid adding unnecessary bracing (additional weight). Finally, for later use in constructing the frame, determine and record all dimensions.

The wooden framework is constructed from one by two inch material (actually 3/4 × 1-5/8-inch). One by two's from a lumberyard are generally of too poor quality. Thus it is probably best to start with reasonably good one by four's and rip them to the one by two size, saving only the portions that are reasonably straight and knot-free. In addition, Masonite triangles about six inches across were added for bracing to strengthen all corners, both front and back around the edge of the frame (see Photo 1). If lances needed to be placed in a braced area, then bracing would only be on the back side.

Although it is possible to use a hammer and nails to assemble a frame, a pneumatic stapler/nailer is greatly preferred. In part, this is because it saves time. More importantly, the frames are somewhat delicate and hammering on them causes more damage than is desirable.

The wooden frame members serve as the base for the placement of the lance nails on the straight segments of the design. For this, either double-pointed nails or thin, 1½-inch brads were used. In the latter case, a side-cutter was used to remove the heads after driving the nails into the wood about ½-inch. The spacing of the lance nails needs serious consideration. If the nails are placed quite close, the design may be more easily perceived by the audience. However, there is added cost, plus, during operation the design may be obscured by the additional smoke generated. An average spacing of four to six inches is probably best for most designs.

The traditional rattan was not used in the method described here; rather what the authors came to call "aluminum rattan" was used. Actually, this is coaxial cable used by the cable TV companies for their trunk lines. It comes in various sizes, but what was used is about ½-inch in diameter. It has a central copper wire suspended in plastic foam, inside a thin aluminum tube. It has two very desirable characteristics. First, it is inexpensive (often free) as the cable company has many short ends, and, because of the mix of materials, most scrap yards do not want it. Second, and more importantly, once it is bent into a shape, it will hold that shape permanently or until re-formed to adjust the lancework figure. However, before bending the material into shape, generally, it is best to install the lance "nails". Using a pneumatic staple gun with ½-inch wide by 1½-inch long staples, drive staples through the cable (aluminum rattan). If a small work stand is made with holes that are four and six inches apart, this can serve as a work station with a built in gauge for rapid stapling every four or six inches. Note that the staples provide two "nails" at each point; a redundant nail for later use if one becomes damaged beyond use. Also, if there is a critical lance point (e.g., a single lance for an eye), the extra "nail" can be used for a second lance, thus guaranteeing that the eye appears during the performance. Once stapled, the rattan is ready to be formed into the needed shapes. Care must be taken in making tight bends so that the cable does not kink. However, with a little practice, even fairly tight bends can be easily made. When the segments have been formed into shape, they can be stapled into place on the lance frame. As a minimum, the ends of each rattan segment must be firmly attached to the frame (i.e., there should be no dangling ends). Photo 1 illustrates the lance frame construction technique described here.

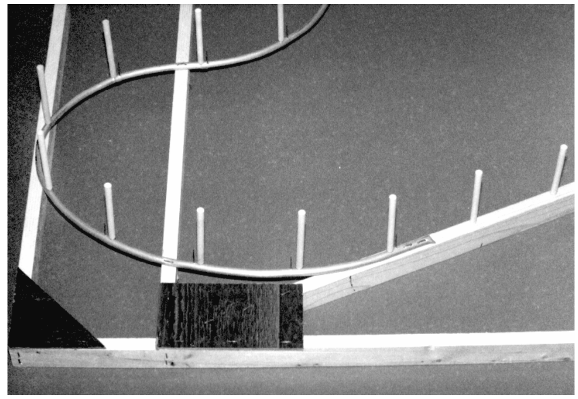

Photo 1. Photo of a lance frame illustrating frame members as lance supports, aluminum rattan and Masonite frame bracing. The frame components remain unpainted in order to be more easily seen in photo.

As the final step, lance frames should be painted with a dark, low gloss paint. In addition to increasing the life of the frame and reducing injuries from wooden splinters in later years, the dark paint eliminates reflected light; so the frame appears invisible to the audience.

Lance Manufacture

There are several sources, both domestic and foreign, for commercially manufactured lance. However, to some extent the cost and certainly the quality of the product leaves much to be desired. The purity of the color is generally poor and most produce incredible amounts of smoke. In fact, some produce so much smoke, that in absolutely calm conditions, the burning lance design can be totally obscured. For these reasons, it was felt that commercially produced lance available at the time was not acceptable. Thus an effort was undertaken to find or develop good lance formulas and an expedient method for lance tube filling.

Commercially manufactured lance tubes are available. Those from Ace Paper Tube (Cleveland, OH) are 5/16-inch diameter, waxed, with spun-closed ends, are 4-5/16-inch long, and are available in a variety of colors. Unfortunately, these tubes have quite heavy walls (about 0.015 in.), which, when waxed, are not easily consumed by the burning lance. It is important that not more than about ¾-inch of lance tube ash be allowed to accumulate as the lance burns (a phenomenon sometimes called “chimneying”). This is because ash extending much beyond the burning surface will seriously weaken, if not completely destroy, the flame color. Thus, if heavy-walled tubes are to be used, it is necessary to have lance formulas that can consume the tubes as they burn. Of course, as an alternative, it is possible to make one’s own thinner-walled tubes (Lancaster, 1992). For convenience, the authors used commercially manufactured tubes and developed lance-tube-consuming color formulas. The resulting formulas, listed in Table 1, produce extremely little smoke (especially in a desert climate), and the colors are all good to excellent, even when viewed in daylight. Since, these formulas were developed over a period of only a few days, working part time, it is likely that additional developmental efforts would yield further improvements in performance. Note also that these compositions all use ammonium perchlorate and some combine ingredients that may cause problems in more humid climates. Thus, at least some added precaution may be appropriate if they are to be generally used. As an alternative, T. Shimizu (Lancaster, 1992) presented a series of good lance formulas. How-

Table 1. Primary Color Lance and Lance Prime Formulas.

Chemical	Red Star	Red Lance	Green Lance	Blue Lance	Lance Prime
Ammonium perchlorate	31	37	37	39	—
Potassium perchlorate	31	10	10	15	58
Red gum (Accroides)	15	8	8	3	6
Hexamine	—	8	8	5	—
Strontium nitrate	—	30	—	—	—
Strontium carbonate	23	7	—	—	—
Barium nitrate	—	—	37	14	—
Manganese dioxide	—	—	—	3	—
Rice starch	—	—	—	6	—
Paris green[(a)]	—	—	—	5	—
Copper metal	—	—	—	10	—
Silicon (325 mesh)	—	—	—	—	12
Titanium (325 mesh)	—	—	—	—	12
Charcoal (air float)	—	—	—	—	12
* Burn Rate (sec/inch)	—	25	23	24	—

(a) Paris Green is actually copper acetoarsenite.

* As determined by C. Jennings-White.

ever, these were less successful at consuming lance tubes and, because of their low density, were not suitable for the rapid lance tube loading technique discussed below.

The basis for the authors' lance formulas was a red star formula, published by S. Bases (1978), that was described as slow burning and possibly suitable for a lance. The burn rate was appropriate for lance and the color was excellent. Unfortunately, the composition did a poor job consuming commercial lance tubes as it burned. The growing length of ash pipe as the lance tube burned would weaken then destroy the color. Simply increasing the percentage of oxidizer did not work as it weakened the color and still did not burn off the ash pipe. Eventually it was discovered that using strontium nitrate and hexamine consumed the lance tube ash well enough for use. Thus the Bases' formula was modified; replacing some potassium perchlorate and strontium carbonate with strontium nitrate, and replacing some red gum with hexamine (see Table 1).

The green lance formula is simply the red lance formula with barium nitrate substituted for the strontium salts. The blue formula was considerably more difficult to develop because copper nitrate cannot be used because of its hygroscopicity. After many trials, a formula was found that produced good color and consumed the ash from the lance tubes. Unfortunately, to get a good color, copper metal had to be used. Note that some pyrotechnists believe that the combination of copper metal and ammonium perchlorate presents a potential safety problem. While the authors never had a problem with this combination in the desert, it is not certain that others would not, especially in more humid regions of the country. Also, when this formula was developed, Paris green (copper acetoarsenite) was still available and often used in blue star compositions. Copper oxychloride could probably be substituted directly for the Paris green and, with some additional development, the use of copper metal might be eliminated. For a possible starting point, one might consider Shimizu's (1980) blue formulations B-1, B-2 or B-3 in Table 4. The prime formula was developed to ignite easily, burn hot, produce short whitish spark (for aesthetic reasons), and contain an alcohol soluble binder (discussed further below).

The red and green formulas combine ammonium perchlorate and a nitrate, thus raising the question as to whether hygroscopic ammonium nitrate might be formed. This double decomposition reaction requires the presence of moisture to proceed. Thus the question might seem to be whether a humid climate might allow the reaction to proceed. However, because the relative solubilities of the reactants are both much less than the products, the possibility of forming a significant amount of ammonium nitrate is eliminated. This is true for both strontium nitrate and barium nitrate, but is just the opposite for potassium nitrate. Thus the red and green formulas should not draw moisture from the air, but a potassium nitrate based prime could. This is the reason why the prime used had potassium perchlorate as the oxidizer.

Table 2 lists a series of formulas for colors achieved by mixing primary colors. The methodology is essentially that described by J. Baechle (1989) and R. Veline. For example, yellow is made by mixing the red and green compositions. The beauty of this method is that it makes it almost trivial to adjust the color to suit ones need or preference. For example the yellow can be shifted toward orange by reducing the percentage of green composition. Analogously, yellow can be shifted toward chartreuse by reducing the percentage of red composition. In much this same way, many different colors and shades can be created.

Table 2. Composite Color Lance Formulas.

Composition	Yellow	Orange	Chartreuse	White	Purple	Aqua
Red lance comp.	25	60	14	14	60	—
Blue lance comp.	—	—	—	28	40	25
Green lance comp.	75	40	86	58	—	75
* Burn Rate (sec/inch)	24	—	—	—	25	—

* As determined by C. Jennings-White.

When making lance composition in preparation for loading into tubes, it is important to know approximately how much to prepare. Using the commercial tubes mentioned above, about 65 lances can be filled per pound of composition (approximately 7 grams of composition per lance).

One traditional method of filling lance tubes is the "rod and funnel" method. This involves using a small stemmed funnel that fits a short distance inside the end of a lance tube. The funnel is filled ½ to ¾ full of composition. Then by working a small rod up and down through the composition and into the lance tube, composition is passed into the tube and compacted somewhat, at the end of each stroke.

The rod and funnel method works well and is quite efficient when filling only a few lance tubes (less than a few hundred). However, when thousands of tubes need filling, other methods should be considered. Commercially, a commonly used method is gang pressing. In this method, the lance tubes are held securely in a matrix and compaction is accomplished using a matching set of rods mounted in a block. After each increment of composition is added to the tubes, the set of rods are inserted into the tubes to consolidate the powder. Another method, developed by the authors, proved to produce satisfactory results, used less expensive equipment and was possibly faster. This method might be called "inertial compaction" and is described below.

With inertial compaction, empty lance tubes are first loaded tightly into a container; during initial trials, a three pound coffee can was used. Later a special container was constructed (see Figure 2), which held more tubes and provided a ready method of removing the filled lance tubes. The container was basically a box made of aluminum, approximately 8 × 8 × 6 inches deep. It had an overhanging lip, which served as a handle. Inside the container were two inserts, which could each hold 200 lance tubes, and allowed the completed lances to be more easily raised from the main container. On those occasions when less than 400 tubes of one color were needed, wooden blocks were inserted to take the place of 100, 200 or 300 tubes.

Once the lance tubes were loaded (snugly packed) into the container, loose lance composition was dumped in and spread around using a small (one or two inch) paint brush. Only enough composition was used to approximately fill all the tubes with loose composition. Then the container was firmly and repeatedly bumped (dropped from a height of a few inches) against a solid wood surface for a total of at least 50 blows (requiring about 30 seconds). As the lance composition compacted itself with each blow, the level of lance composition in the tubes was lowered. Then more loose composition was added to refill all the tubes, after which the container was bumped again to further compact the composition. The process was repeated until after compaction (bumping) the level of composition in the tubes remained within about 1/8-inch of the top.

This remaining space was filled with prime, which contained red gum. After loading the loose prime and brushing it around, the container was again briefly bumped to compact the prime. Finally, the exposed tops of the lance were sprayed with a small amount of isopropyl or ethyl alcohol. The alcohol dissolves some of the red gum to activate it as a binder. When the alcohol evaporates, the prime becomes reasonably hard and seals the weakly compacted com-

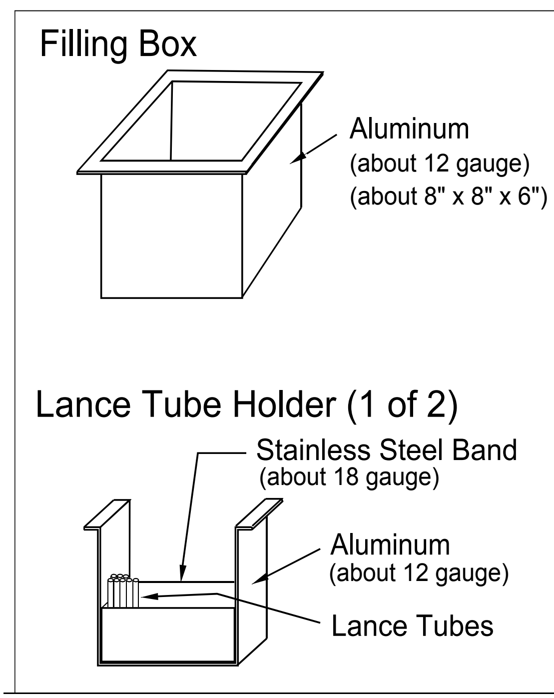

Figure 2. Drawing of the lance tube filling box and one of two lance tube holders, which were contained within the filling box.

position in each tube. Normally it took about 15 minutes to complete the filling of one container of 400 lance tubes.

Since the lance tubes were tightly packed into the filling container, not much lance composition was wasted by filling the spaces between the tubes. However, the excess composition was collected and re-used, even though it contained a small amount of prime. For this reason, it is important that the prime be chemically compatible with the lance formulas.

Manufacturing safety should always be of some concern, perhaps even more so in this case because of the compaction technique described. Note that the box is made of aluminum and the bumping surface is wood. These are quite forgiving in terms of likelihood of accidental ignition due to impact. Although the lance formulations reported in Tables 1 and 2 were not tested for their impact sensitivity, it is suspected that they are likely to be of relatively low sensitivity. Lance compositions are generally slow burning and thus are less likely, than star composition, to react explosively when ignited, even in moderately large amounts. Accordingly, accidental ignition of these lance compositions seems unlikely and the chance for explosive burning seems minimal. Nonetheless, the bumping surface should be kept clean with respect to lance composition, there should be no more composition in the immediate work area than necessary, containers should be kept covered, completed lance should not be allowed to accumulate in the work area, there should be only one person working in the lance loading area, and there should be at least one other person working nearby that could lend assistance in case of an accident.

One drawback to this manufacturing method is that the completed lance tubes are not completely clean on the outside. Nonetheless, they work well and can be cleaned if desired. One cleaning method is to simply wipe the tubes with an alcohol dampened cloth.

Often commercially produced lance is filled a short distance on the bottom with clay or fine sand. This can be useful in adjusting burn times of the various compositions so that all colors of lance burn out after nearly the same length of time. For those compositions that burn slower, more inert filler can be used at the bottom of the lance tube. The inert filler also acts to extend the life of the lance nails, because they are not exposed to burning composition. If desired, small fixed amounts of clay or fine sand can be preloaded into each lance tube before loading them into the filling container.

For this tube-filling method (inertial compaction) to work, it is necessary that the lance composition be fairly dense, and for all the components of the formula to have about the same density. This is one reason why Shimizu's lance formulas, mentioned earlier, were not used. They all contain wood meal (ultra-fine wood dust), which produces a composition that is light and fluffy. This greatly retards, or eliminates, the ability to sufficiently compact the composition in the tubes with just bumping. Also, the wood meal has such a low density compared to the other ingredients that it tends to separate out, rising to the top, during the bumping process. This tends to produce essentially incombustible layers of wood meal along the length of the lance tubes. Also, there was a period when the ammonium perchlorate most commonly available to the fireworks trade was extremely fine mesh. Use of this material caused the compositions to compact very poorly using the bumping method; it is preferred that the ammonium perchlorate (and other ingredients) be no finer than about 100 mesh.

An interesting variation is the making of color changing lance. This requires that the tubes be filled part way with different color compositions. To be effective, it is essential that all tubes in a group change color essentially simultaneously. About the only way to accomplish this is first to fill each tube with measured amounts of composition. After each tube is filled with the first composition (last color burned), it is compacted as described above. Then each tube is filled with the next color composition and compacted. After all the different color compositions have been loaded, the final step is the filling with prime as described above. In this way lance with one or more color changes can be prepared.

Completed lance were normally stored in plastic containers or in plastic bags in boxes. On occasion lance were stored for several years before use without any detectable deterioration. However, no attempt was ever made to determine their useful lifetime or whether problems might arise with their long-term storage particularly in more humid climates. It is important to avoid rough handling of the lance, because the prime coating can be broken and the loose powder below can then spill out.

Final Lance Set Piece Assembly

The first step in set piece assembly is to press the correctly colored lance on each nail of the frame. This is done by holding the lance tube firmly along its body and pushing it onto the nail. Occasionally, when the frames were not to be stored for a long time and did not have to be transported a great distance, the tubes were not glued in place. This is possible because the filled tubes hold fairly tight to the nails, particularly after the nails have been burned from previous use. In addition, the frames were always transported horizontally, with the lance tubes pointing upward, thus there was less tendency for the tubes to loosen. However, for more positive attachment, the lance tubes should be glued into place with a small amount of glue applied to their bottom ends. This can be rapidly accomplished using a small shallow tray filled with about ¼-inch of carpenter's. (Hide glue and RTV cement are other alternatives.) The spun-closed end of the lance tube is dipped momentarily into the glue just before it is placed onto the nail. If desired, more glue support can be achieved by using glue thickened with an inert filler such as diatomaceous earth or wood meal.

The next step is to attach fuse to the collection of lance tubes. Many people use masking tape to hold the quick match to the lance tubes; others use string, looped first around the quick match and then around the frame to hold the match against the end of the lance tube. Masking tape does not hold particularly well, especially when exposed to the sun on a hot day; and the string method seems quite labor intensive. As an alternative, the authors used two-inch wide, plastic packaging tape of reasonably high quality to quickly secure the quick match. This method worked most efficiently when two people worked together. As the quick match is held across the top of a lance tube, a three or four inch length of tape is placed across the quick match and onto the sides of the tube. Next the two sticky surfaces of the tape, on either side of

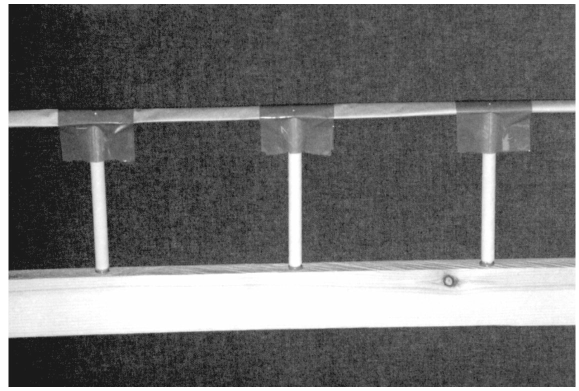

Photo 2. Photo of quick match attached to lance tubes using plastic packaging tape.

the lance tube, are pressed together, which draws the quick match down even tighter against the end of the lance tube. Photo 2 demonstrates the appearance of the taped lance tubes. This operation is repeated for the fusing of all lance tubes on the design. The plastic packaging tape sticks extremely well even to slightly dusty or waxed lance tubes, and it has no tendency to loosen with time or under direct sun.

The quick match should be cross-fused in several places, providing multiple ignition paths, and thus better insuring the ignition of the entire design. This can be accomplished by simply holding crossing lengths of quick match together and applying a piece of plastic packaging tape to each side as shown in Photo 3. Similarly, when two or more smaller lance frames are assembled into a single larger unit on site, multiple (redundant) ignition paths should be installed between the individual smaller frames.

The final step is to poke ignition holes through the quick match into the end of each lance tube and through both pieces of quick match at each crossing point. This is easily accomplished using a poking tool such as also shown in Photo 3. This was made by simply gluing a double-pointed nail into the end of a piece of wood dowel. (As an alternative, there are leather working tools that can be used as poking instruments.) These ignition holes are essential to achieve a high percentage of lance tube ignitions. As quick match burns, hot gases are forced along its interior between the black match and the paper wrap. When those pressurized hot gases reach one of the holes poked into a lance tube or crossing point, the burning gases jet out

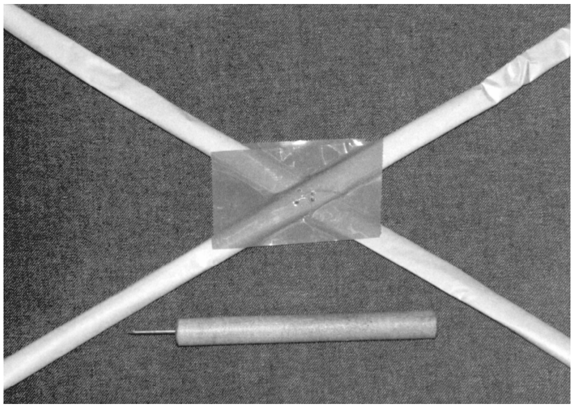

Photo 3. Photo of a quick match cross fusing and ignition hole poking tool.

through the hole igniting what it contacts, lance or other quick match. The poking process also breaks the prime on top of the lance tubes making it more ignitable.

Many in the fireworks industry use narrow staple guns to poke the ignition holes and further attach the quick match to the lance tubes. However, because these staple guns occasionally produce sparks when operated, the use of staple guns should be avoided (Ofca, 1989 and Winokur, 1985).

When spectators see a lance frame before a display, many will recognize it as a lancework and try to figure out what design it will produce. Probably their best clue is the pattern formed by the quick match. If the quick match follows directly around the design, it is relatively easy to successfully identify the design. In order to challenge these spectators, and hopefully surprise them, the authors found it preferable to run the quick match in a pattern which obscures the design. Often this can be accomplished when the extra quick match ignition paths and cross fusing mentioned above are included.

If the set piece is to be fired manually, a length of quick match, long enough for the shooter to easily reach, should be left at some point along the set piece. If the set piece is to be fired electrically, an electric match needs to be installed in the quick match fusing.

When quick match is used to light lance tubes, the entire design is ignited within a second or two. This is accompanied by abundant fire and sparks, and appears almost explosive. Often this effect can add to the drama of the presentation. However, there are occasions when a lancework scene is intended to unfold more slowly and serenely. On occasions, when the use of quick match works against the mood being sought, fast ICI igniter cord (plastic coated, brown, burning about one-foot per second) can be used instead of quick match. The time taken for design ignition ranges from less than five seconds to more than 15 seconds, depending on how the fuse is attached and where it is ignited. In addition to being slower, it burns almost silently by comparison with quick match. Also, some have reported that priming the lance tubes is unnecessary when using this type of fuse. The ICI igniter cord is available from Ladshaw Explosives (New Brunfels, TX) at a cost comparable to quick match. The plastic coating offers good protection from accidental ignition from sparks during a display. It is attached to the lance tubes just like quick match; however, there is no need to poke ignition holes because this fuse produces molten metal sparks as it burns. The fuse is quite light weight and flexible, making it particularly easy to work with. The authors used this fuse about 60% of the time.

Final Display Arrangements

Completed lancework set pieces were often stored in a trailer built for transporting them to the display site. It was metal frame construction with metal siding, making it fire and weather resistant. The trailer held 12 frames horizontally, which were slid in on rails, much like the racks in an oven. Because of the limited number of displays performed by the authors each year, generally all the sets needed over the Fourth of July could be assembled in advance and stored in the trailer. On the day of a display, the frames needed would be loaded in the top most positions and other display materials could be loaded into the space below. On site, the lance frames would be left in the trailer, protected from weather and other possible damage, until just before the display.

Often lance set pieces are better viewed when raised above the ground; other times, because of obstructions, they may not even be visible if the frames are not raised in some manner. Most commonly, this is accomplished by mounting the frames on two by four poles, which are then

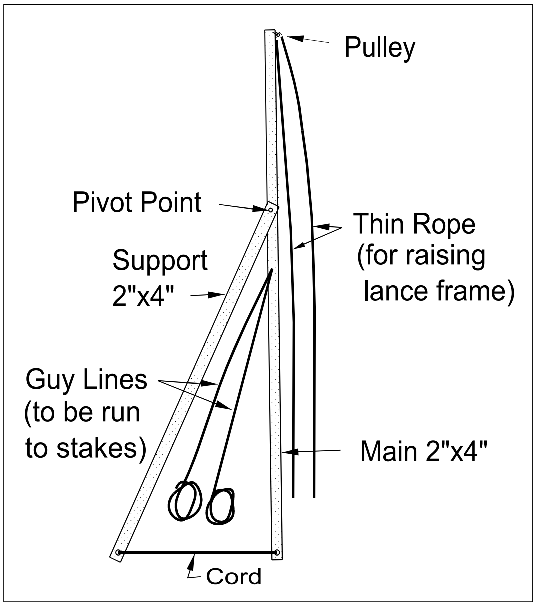

Figure 3. Sketch of an "A-Frame" used to elevate and support lance frames during displays.

erected and secured in some way. Unfortunately, unless the poles are strongly braced, they have a tendency to fall down, especially if an unexpected breeze comes up suddenly. Obviously, few, if any, lancework could survive such a collapse. The preferred support system would be easily transportable, inexpensive, strong and reusable. One solution is the use of "A-frames", shown in Figure 3.

The A-frames consist of two 2 × 4's, one longer than the other, that are loosely bolted together where the shorter one ends. This allows the two boards to pivot about this point. A hole is drilled into the base of each of the boards a cord is tied between the two legs to prevent their spreading too far when being erected. Near the pivot point two ropes are attached on either side of the 2 × 4's. These serve as lateral support guys and are tied to strong metal stakes driven into the ground on either side of the A-frame. (Reusable metal stakes can easily be made by cutting concrete reinforcing steel, "rebar", into short lengths.) Finally, a pulley is attached near the top of the long board with a thin rope threaded through it, long enough for the ends to nearly reach the ground. Pairs of A-frames are erected, about six feet apart, well before the time of the actual display. Then just before the display a lance frame is tied to the ends of the ropes and raised aloft by pulling on the other end of the ropes. This may seem complicated, but they erect quite easily and are quite sturdy even in moderate winds. They also offer the advantage of easily allowing the temporary lowering of the lance frames in the event of strong winds or rain. A-frames can also be used to support display items like Niagara Falls or cable used to suspend moving items like line rockets and small lanceworks. A variety of lengths of A-frames, ranging in height from eight to 24 feet, are useful. They should be painted dark colors for the same reasons as the lance frames. They bundle-up nicely and can be easily transported on racks over trucks or trailers taken to the display site.

It is distracting to the audience, and takes some of the mystery and drama from the presentation, to see a person running around carrying a flare (fusee) to light lanceworks. For this reason the authors always electrically fired their set pieces. Occasionally, this was accomplished by running wires back to the main firing control panel. However, since many lancework set pieces require the presence of an operator for their animation, a hand held firing control unit was often used, see Photo 4. The unit is powered by four C-cells mounted in an external battery pack on the back of the unit, which checks for electrical continuity, and can fire up to five independent circuits. It has separate output plugs for firing single circuits, up to three circuits, and for all five circuits. When it was nearly time to discharge a set piece, the operator would approach the display, plug in and then fire the item(s). In this way the audience never knew which ground display was about to be fired, and when the item was animated in some manner it was not obvious that there was a person in the vicinity who was probably responsible for the movement. (Of course, in those cases where it is practical, the lancework can be driven pyrotechnically.)

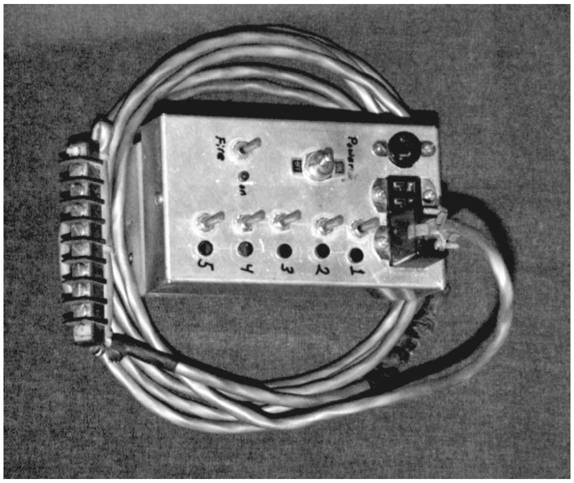

Photo 4. Photo of a hand held electrical firing unit used for the ignition of set pieces. It is capable of testing continuity and firing up to five circuits.

Lancework Presentations

As mentioned in the introduction, a lancework set piece that sits there and does nothing other than burn for 60 seconds is little short of boring. Generally a sponsor should be dissuaded from having these items in the display. Most notable among lancework to be avoided are "WELCOME" and "GOOD NIGHT". They are a waste of time and money during a properly staged display. If you can not make the audience feel welcome by your presentation of the fireworks, no mere sign will accomplish it. Similarly, if the spectators can not identify the finale, then there was not a proper development of the display and it was a pitiful finale. However, for some stationary lancework, there is little or no choice. Among those are sponsor's logos; some sponsors will forego these for more crowd pleasing lancework, others will not. Of course the one stationary display, about which there is no choice on July 4th displays, is the American flag. In this case the solution to boredom is augmentation. After the flag set piece has burned for a while, augment the item with additional fireworks, then a little later augment with still more and grander fireworks. This concept is illustrated in Figure 4 with the American flag (top); then after about 20 seconds it is augmented with some fountains (middle); finally, after about another 20 seconds it is augmented with fountains and Roman candle batteries (bottom). When a company logo or similar stationary lancework is required, again use the concept of augmentation to hold the audience's interest.

While on the subject of the American flag, there are some other points that need mentioning. Obviously the rectangular flag, as used in Figure 4 for simplicity, can be enhanced by adopting a wavy pattern, depicting a flag waving in the breeze. It can be further enhanced with the addition of a flag staff and halyard. However, anyway it is configured; the flag is more nearly a solidly painted display, as opposed to an outline. Thus it generally requires many more lance tubes than other lancework designs of similar

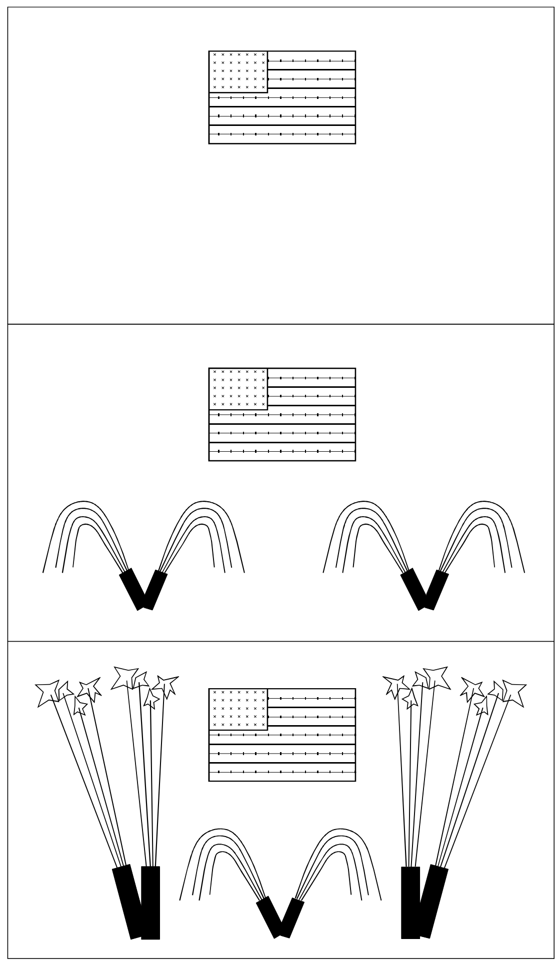

Figure 4. (Top) Sketch of American flag lancework. (Middle) Example of flag set piece augmented with fountains. (Bottom) Example of flag set piece augmented with fountains and candle batteries.

size. Obviously this means more cost for lance and assembly, which is of some importance. Perhaps less obvious, but more importantly, it means much more smoke, which can seriously detract from the performance. In addition to using low smoke lance formulations, one can reduce the number of stripes from 13 to 11. This will reduce both smoke and manufacturing cost by 15%, and essentially no one will notice the missing stripes. Also, do not attempt to include 50 stars; in fact, do not include any stars. It is the blue field plus red and white stripes that define the flag. Adding stars, washes out the effect of the blue field and adds unnecessarily to smoke production.

In the introduction it was suggested that most lancework set pieces should be animated or otherwise engage the audience. "Animated" simply means that the item or part(s) of it should move, this will surprise most spectators and please all of them. By "otherwise engage the audience" can mean nothing more than augmentation as described above, but generally it means to use individual lancework figures as characters in a skit. The remainder of this section will demonstrate such animation and engagement by discussing some examples.

Perhaps the simplest example of animation is that demonstrated in Figure 5. Top left is the figure of a pumpkin, a sad pumpkin. Top right is a happy pumpkin. The manner of changing the pumpkin's mood is illustrated at the bottom of Figure 5. Here the horizontal row of connected dots is intended to represent the mid-section of the pumpkin's mouth. At either end of that section is attached a thin board with four additional lance tubes. These boards are only attached to the framework on the end toward the middle of the pumpkin mouth, and that attachment point is a pivot. The outer ends of the boards have a thin cord attached, which is fed through eyelets on the lance frame. The board to the left is illustrating the sad pumpkin mouth, while that on the right is for the happy pumpkin. This design was once used in a display, staged for Halloween, at a State Home for the retarded. First the lancework was ignited as the sad pumpkin (orange pumpkin, green stem, red eyes and mouth). Of course, pyrotechnicians are familiar the expression, "Fireworks Make *Pumpkins* Happy". Thus, after the set piece burned for awhile, a collection of fountains and other items were ignited in the

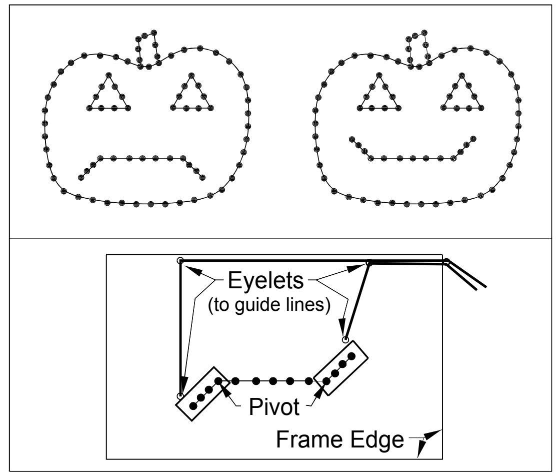

Figure 5. (Top Left) Sad pumpkin figure. (Top Right) Happy pumpkin figure. (Bottom) The simple mechanism used to manipulate the pumpkin's mouth.

vicinity of the pumpkin, which caused its expression to change into the happy pumpkin (by pulling the cords). Obviously this was a trivial addition to the lance design, but the degree to which it contributed to a delightful reaction of the audience would be hard to overstate. This display was enhanced by being performed to some circus music. During the sad pumpkin phase, the music being played had been recorded at half speed, then when the augmenting fireworks were being shot, the speed of the recording was corrected, reinforcing the pumpkin's mood change.

A some what more complicated example of this type of animation is presented in Figure 6. This is a sequence of views of a fire breathing dinosaur (dragon) in action. The top view is the initial presentation to the audience (green dragon with a bright red eye). After about 20 seconds, the dinosaur rears back its head and belches out some red fire with silver sparks. After another 20 seconds, the dinosaur leans forward, belching more fire and sparks, this time igniting a candle battery of angry bees, which finally causes the dinosaur to again rear back its head.

To avoid the chance of premature ignition of the candle battery and also to be certain of ignition on cue, the candle battery was fired electrically. For the dinosaur to have a friendly appearance, it was made to look somewhat like the Flintstone's Dino, with a bulbous nose. Because

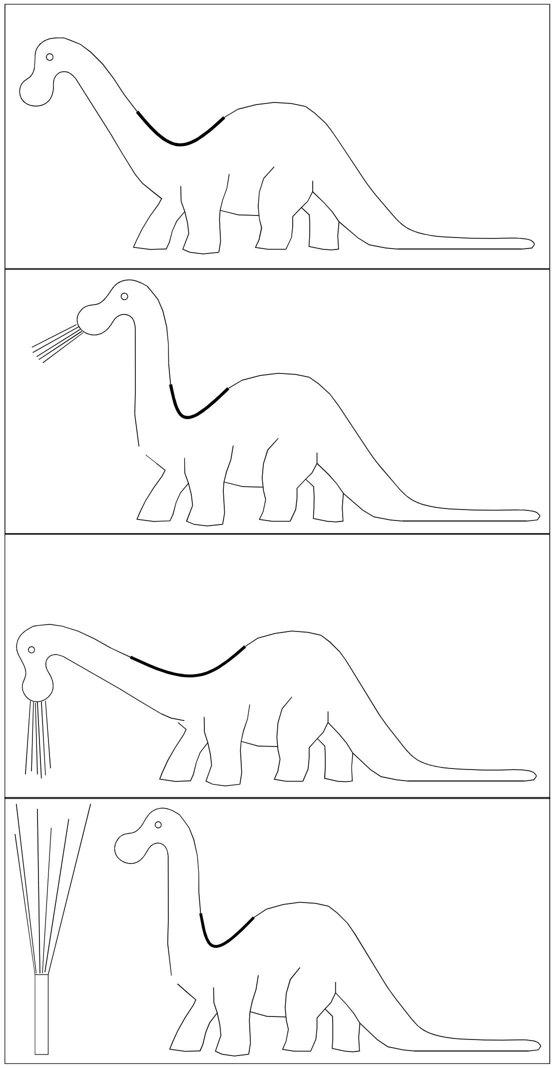

Figure 6. Sketches of dinosaur lancework. (Top) Initial view. (Upper Middle) Dinosaur rears head back and breathes fire. (Lower Middle) Dinosaur lowers head and breaths fire, which "ignites" a candle battery (Bottom) causing the dinosaur to again rear its head back.

the eye is a particularly important part of the lance figure, it was made with two lance tubes, thus doubling the chances at least one would light.

The mechanism of the Dinosaur's animation is illustrated in Figure 7. Here note that the entire head is a separate part of the figure, and is attached at a pivot point near the bottom of its neck. Motion of the head is controlled with a thin cord attached to the back of its neck, by an operator standing at the end of the frame. The puffs of red fire are created using red lance composition "spiked" with 20 to 40 mesh titanium. This is loaded loosely into a tube and ignited with an electric match. The aspect of this design that makes it work is a segment of "flexible rattan". The flexible portion is a piece of ½ inch garden hose with a series of lance attachment points, which are two inch brads nailed through the hose and tightly through a small disk of 1/8-inch tempered Masonite. The hose section is only attached at the ends, leaving the middle to take various natural bends as the head is manipulated. In this case the light hearted mood of the lancework might be enhanced by using Tchaikovsky's "Dance of the Sugar Plum Fairies" as musical accompaniment.

A simple example of another type of animation, where the whole figure moves, comes from the same show at the State Home discussed above. In this case the lance figure was that of a ghost. What is one obvious characteristic of ghosts? They float through the air, and, it will be a little scary if it floats toward the observer. In this instance, the ghost figure was attached to a cable running from the top of a 24 foot tall A-frame (discussed above), running about 50 feet toward the audience where it was attached to an eight foot tall A-frame. The lance frame was ignited while high in the air. After a while, a mine was discharged under the ghost, and it swooped part-way down toward the audience. This sequence was repeated a couple more times, each time coordinated with the music.

Basically this same method of animation (frame on a cable) can be used to provide an interesting variation of the "Fish in Niagara Falls".

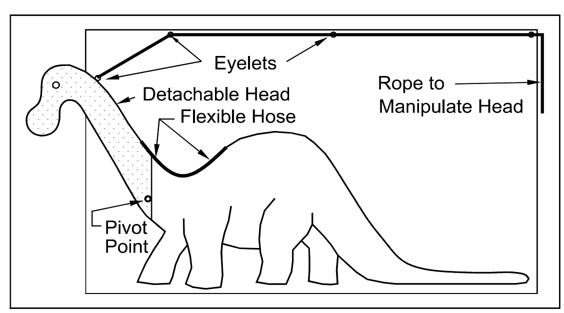

Figure 7. Construction details for dinosaur lancework, illustrating mechanism and location of "flexible rattan" segment.

This is where a lancework consisting of two or three fish is ignited (before, after, or simultaneously) below a standard Niagara Falls. For one possible variation, initially have the falls and fish separated, right to left, thus having the fish out of the water. Then after both are ignited, have the fish swim into the falls. That is to say have the fish lance frame suspended on a cable, then with a cord, pull the fish under the flowing falls. Another variation starts out the same with the fish out of water, but this time the falls are moved to where the fish are. This uses a stationary lance frame, but the falls have to be operated in a manner somewhat like a curtain on a rod. By varying the program like this, the same lancework can be used for the same display for several years running, and those people most enjoying the performance will be those that have seen the previous versions.

Animation can also combine moving parts of a figure and motion of the figure itself. Probably the most complicated example of this was a steam locomotive, appearing much like the "Little Engine that Could". In this case a cute little steam engine first appears, with its driver wheel, piston rod and cylinder, smoke stack (funnel), etc. Then after a little while it begins to puff smoke and fire from its stack and it starts to move along the ground. At the same time, and consistent with its motion, its drive wheel rotates and piston rod moves, along with its other wheel.

The smoke and fire are accomplished with a battery of tubes mounted behind its stack, each charged with several grams of black powder and perhaps some fine titanium. The battery is fused with a moderately fast fuse such as Thermolite (Cooney's Explosives, Hobbs, New Mexico). The delay between the initial tubes should be about two seconds, and the delay between tube firings should decrease as the engine speeds up. The speed of Thermolite used will depend on the size and arrangement of lances being used. Of course, the motion along the ground is accomplished with a person pulling on a rope. The wheels are plywood disks mounted on bearings at their center. Its rotation is made to be consistent with the motion of the engine by simply having the wheels touch the ground, thus having the motion of the figure along the ground provide the rotation of the wheels. There are, however, a couple of things that should be made more clear. First, the lance frame needs to be attached to a skid of some sort to keep it from falling over when pulled along the ground. Any of a number of designs will work; the authors used an out rigger from the back of the frame with a wheel on it. This along with the train wheels made the lancework easy to move and easy to setup. In order to keep the moving piston rod from knocking off the lance tubes on the driver wheel it had to be moved out in front of the wheel to provide clearance for the lance tubes. Similarly, where the piston rod moved inside the cylinder, it is necessary to have clearance for the lance tubes on the piston rod. It is also necessary to have the cylinder be solid (thin plywood) so that the lances on the piston rod will not be seen as they seem to move inside it.

Another effective way to use lancework is in the acting out of a brief skit. A simple example of this is illustrated in Figure 8. The first scene rivals two cute little tanks facing one another. One, "Nasty Tank", decides to be a bully by starting to fire on "Good Tank" who just sits there and takes it. The audience may start to cheer now rooting for Good Tank to start firing back, which it never does. Finally, "Powerful Tank" erupts onto the scene unleashing a short intense burst of gunfire toward Nasty Tank. There is a powerful explosion and Nasty Tank is no more. By now the crowd is cheering madly. This provides lots of entertainment and a message too. Be careful about picking fights, there will always be someone bigger, tougher, or meaner than you.

A few points need mentioning regarding the mechanics of the tank skit. The cannon fire from Nasty Tank should be slow paced and anemic, such as that which might be produced using a single "color with bangs" roman candle. The cannon fire from Powerful Tank should be brief but intense, such as might be produced by a battery of single shot silver comets fused to fire essentially simultaneously. There is a large salute (about three-inch) mounted directly behind Nasty Tank, which is fired at the same time the comets from Powerful Tank arrive on target. Nasty tank disappears, but not because it is blown up, which could send debris toward and possibly into the spectators. Nasty Tank is setup leaning slightly forward toward the audience, only kept from falling by a light cord securing it from behind. This cord is tied around the large

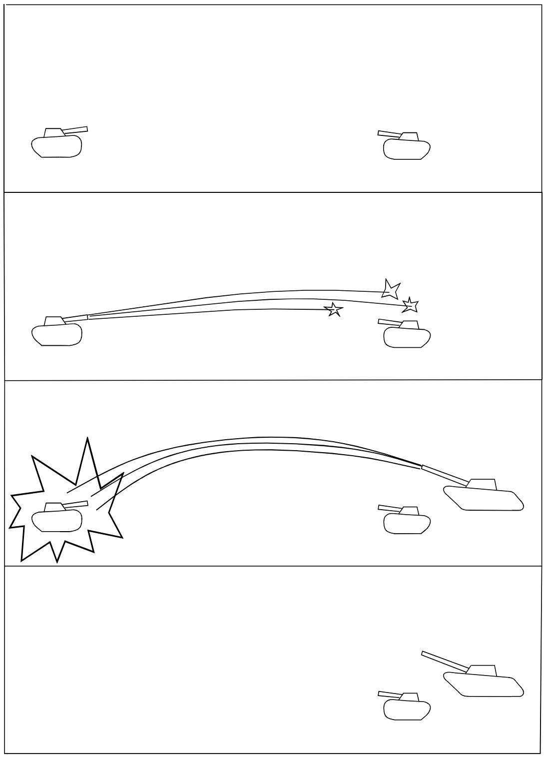

Figure 8. Sketches of a tank battle scene. (Top) Initial view. (Upper Middle) "Nasty Tank" begins to fire at "Good Tank". (Lower Middle) After a while "Powerful Tank" appears, fires at Nasty Tank, which explodes violently. (Bottom) No more Nasty Tank.

salute mentioned above. When the salute explodes, the cord is severed, allowing Nasty Tank to fall forward snuffing out or obscuring the lance flames in the grass as it hits the ground.

There are two other skits with much the same message as the tank skit. The first might be called "Little Fish, Big Fish". In this case, the first scene is of Little Fish and a worm in front of it. Little Fish moves forward, opens its mouth, swallowing the worm, which disappears inside. Next Big Fish appears behind Little Fish. Big Fish swims forward, opens its mouth, swallowing Little Fish. The only detail needing mention here is that the fish need to have big mouths and they must be solid so that what is seen to be eaten disappears. The other skit with similar theme begins with a hot air balloon inflated but on the ground and a figure of a man standing nearby. The burners in the balloon are fired, after which the balloon rises slowly into the air. Next someone in the balloon throws out a bomb blowing up the guy on the ground. Then an old biplane suddenly appears in the air above the balloon, it fires a burst of machine gunfire at the balloon, causing it to plummet to the ground. In this case, the balloon burners are specially made short duration fountains. The balloon is initially on the ground but has been set in front of a pair of 24-foot tall A-frames. Using ropes, the pulleys on top of the A-frames, and (strong) manpower, the balloon can be raised and later lowered. The biplane is supported off the ground using another pair of A-frames.

As one last example of a skit with moving parts, consider the following, used in conjunction with a series of annual displays fired for the Junior College World Series of Baseball. Imagine how a scene might appear with some kids playing baseball behind a fence, such that only part of the action and not the kids themselves can be seen. This is illustrated in Figure 9 in which the fence is actually the outfield fence in the ball park. In the first scene, the ball has been pitched and is approaching the batter (bat). The batter swings striking the ball and the crack of the bat is heard (and seen too). This is produced by a salute on top of a thin pole such that it is positioned just behind where the bat appears to contact the ball. The ball is now moving in the opposite direction sailing toward the outfield. At the last minute a gloved hand is seen reaching up from behind the fence to catch the ball. At this point there are three ways for the skit to conclude. In version one, the ball stops in the middle of the glove, the catch having been successfully made. This is noted by displaying the word "OUT" on a lancework banner above the glove. In version two, the ball approaches the gloved hand still rising and the ball continues over and beyond the glove. Obviously a home run that can be announced on the banner as "GONE". In the final version, the ball stops momentarily in the glove then falls to the ground. Obviously this is an error, which is announced as "OOPS". The beauty of this skit is that it can be re-played again and again; each year with the audience never being sure what will happen, and each year with the most favorable response coming from those in the audience that have seen one or another version of the skit before.

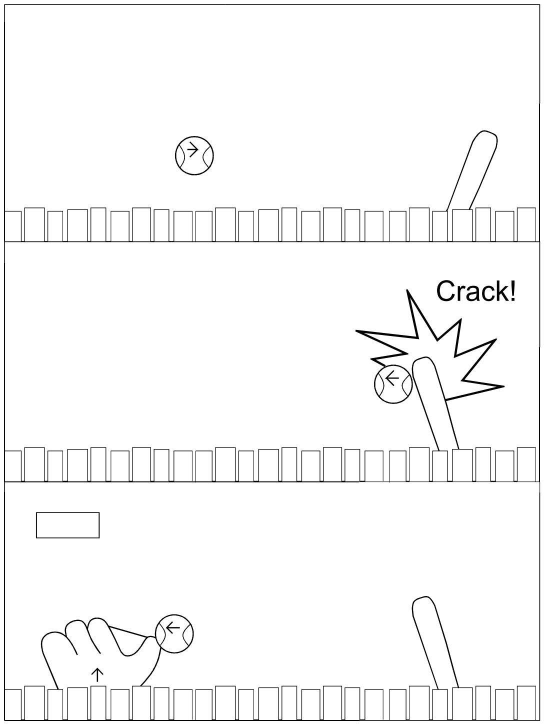

Figure 9. Sketches of baseball scene. (Top) The baseball is seen approaching the bat. (Middle) The bat is swung forward, striking the ball with an explosion and sending it in the opposite direction. (Bottom) As the ball continues to move, a giant mitt reaches up to catch the ball.

Conclusion

Lancework set pieces can be one of the most crowd pleasing types of fireworks, or they can be a bore. It is strictly up to you and your imagination. If one uses high quality lance formulas, skillfully designs the lance figures, provides clever animation or tells and interesting story, the entertainment value of lancework can reach the heights that it should.

Acknowledgments

The authors wish to express their gratitude for the assistance of G. Roberts in the design and construction of some of the lancework discussed in this article. Further, the authors wish to thank the Pyrotechnica Staff and especially C. Jennings-White, R. Winokur and M. VanTiel for their technical comments and editorial assistance, and for their contributions appended to this article.

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Appendix A

Supplemental Lance Formulations

Clive Jennings-White

Ingredient	Red	Orange	Yellow	Aqua	Blue	Purple	White
Ammonium perchlorate	30	75	—	30	—	50	—
Potassium perchlorate	35	—	60	5	55	20	75
Accroides resin	5	—	—	10	—	10	20
Hexamine	10	—	—	4	—	—	—
Strontium carbonate	20	—	—	—	—	10	—
Barium nitrate	—	—	15	45	—	—	—
Shellac	—	15	15	—	—	—	—
Calcium carbonate	—	10	—	—	—	—	—
Sodium oxalate	—	—	10	—	—	—	—
Benzoic acid	—	—	—	5	—	5	—
Cupric carbonate	—	—	—	1	—	—	—
Lactose	—	—	—	—	25	—	—
Cuprous chloride	—	—	—	—	15	—	—
Parlon	—	—	—	—	5	—	—
Cupric oxide	—	—	—	—	—	5	—
Dextrin	—	—	—	—	—	—	5
Burning Rate (sec/inch)	29	25	30	20	22	23	24

Comments on Supplemental Lance Formulations in above Table

Red — A slight modification of S. Bases' (1978) formulation number 4. This might be suitable for use in particularly humid climates, where strontium nitrate could cause a problem. Otherwise the formulation given in Table 1 is superior in all respects.

Orange — A formulation given by T. Shimizu (1981). This very superior orange lance composition is effective in both hand rolled and commercial lance tubes. However, it may not have a sufficient density for the filling method described in the text.

Yellow — A formulation given by T. Shimizu (1983), which is a good balanced yellow, but it produces a fair amount of smoke as it does not contain ammonium perchlorate. One should not assume that it is free of hygroscopicity problems, because the combination of barium nitrate and sodium oxalate undergoes double decomposition to produce sodium nitrate.

Aqua — A modification of J. Baechle's (1989) system five aqua. This works well in both hand rolled and commercial lance tubes. The color is more towards the green than that produced from the composition in Table 2.

Blue — Previously published (Jennings-White, 1990). This composition is useless in commercial lance tubes, but in hand rolled tubes the effect is second to none. However, there is substantial smoke production because there is no ammonium perchlorate.

Purple — Previously unpublished. This works well in both hand rolled and commercial lance tubes.

White — A slight modification of Ellern's (1968) formulation number 39. This produces a "warmer" white than the composition in Table 2, and also it has the advantage of formulation simplicity. It is effective in both hand rolled and commercial lance tubes. However, there is substantial smoke production because there is no ammonium perchlorate.

Appendix B

Some Additional Thoughts

Martin VanTiel

Lancework Burn-out — An artistic preference, when the lancework nears burn-out, is to lead the audiences view into the sky. This will distract their attention away from the lancework while each lance finally burns out in a disorderly fashion. In the minds of the audience, the lancework will be remembered in its full glory while the display continues. This can easily be accomplished by the use of a flight of rockets or tailed aerial shells.

3D Lancework Design — A further development in the presentation of lancework which one should not overlook, is that of the third dimension. Three dimensional lancework has the advantage of being viewed generally from all directions unlike 2D framework designs. This is well suited for displays where the audience is not situated in one viewing position. Also, due to the relatively non-hazardous nature of lancework ground displays, they are generally situated in close proximity to the audience and viewing at obtuse angles is not very rewarding. The 3D lancework can be rotated or moved on a trolley arrangement, so that all sides can be viewed. The artistic potential is limited by time and cost, but novelty, amazement and wonder will be enjoyed for a lot longer.

Lancework Chemistry — There are some aspects of chemistry that need to be considered with lance compositions. One very important aspect is that the lance tube is to be considered as fuel. The lance tube is required to burn away during operation and therefore lance compositions generally have a high percentage of oxidizers in order to accomplish this. An oxygen rich flame is not considered to provide the best color and therefore one must find a balance between tube burning and flame color. Obviously the thinner the wall of the lance tube, the easier a composition can be developed to burn the tube away.

The use of low energy fuels, (defined as organic compounds having a high percentage of oxygen, chlorine or nitrogen) such as cellulose (or wood meal), hexamine or PVC, require small amounts of oxygen to burn completely. These fuels can be used at a moderate percentage to give oxygen rich combustion to enable the tube to burn away. These low energy fuels also have lower flame temperatures, which are useful in blue lance compositions. High energy fuels (defined as hydrocarbon compounds with little or no other elements) such as stearic acid, wax, gums and resins require large amounts of oxygen to burn completely. High energy fuels must be incorporated at a low percentage so that the tube may burn away.

Red and Green, High Energy Fuel Lance Compositions.

Ingredient	Red	Green
Ammonium Perchlorate	80	60
Strontium Carbonate	10	—
Barium Nitrate	—	30
Fuel	10	10

The use of ammonium perchlorate has obvious advantages in lance compositions, no smoke (dry air), no ash, available chlorine. The disadvantage of ammonium perchlorate is that it is not suitable for use with potassium nitrate compositions because of the possible production of hygroscopic ammonium nitrate.

Another consideration can be the use of suitable organometallic compounds based on copper, strontium, barium, etc. (cost and availability permitting) with ammonium perchlorate along the lines of Bleser's (1987) blue formulation based on copper benzoate. This provides two component compositions readily adjusted to suit color and tube burning.

Appendix C

Some Lancework Ideas

Robert M. Winokur

An inspection of display fireworks company catalogues from the 1940's, '50's, and '60's reveals an assortment of lancework illustrations that are a valuable source of ideas for those wishing to build lanceworks. Below I have summarized some of these and added a few derived from my own experience. I claim no special originality for any of these ideas. Indeed, catalogues spanning over 100 years often contain identical or very similar drawings, indicating significant "borrowing" between companies. Some of the lanceworks are listed with little or no explanations of mechanisms of animation. The reader will need to devise the mechanisms themselves, although in most instances movement can be achieved without especially complicated designs. In fact, a serious attempt should be made to keep all mechanisms as simple as possible to avoid technical "traps" which can cause failures during a performance. In a few instances I have provided brief explanations and recommendations with regard to structural designs, animation mechanisms, and pyrotechnic considerations. It is hoped that this list will become a useful and convenient resource when planning lanceworks.

Rocket to the moon — A large lancework rocket with a gerb as the motor is pulled along a cable towards a crescent-shaped lancework moon. Rocket—red, gerb—silver, and moon—white or yellow.

Sea lion bounces a large ball on his nose.

Old time car — Wheels turn, radiator steams and car backfires (small ground bombs).

Mother circus elephant washes baby elephant while the baby sits in a tub — Spray from Mother's trunk achieved with a silver gerb.

Pelican eats multiple small fish — Movable bill on the pelican catches a number of "fish" in the form of either line rockets or small lancework fish pulled on a cable.

Liberty bell with crack — Patriotic theme.

Boy fishing with pole catches a fish.

Basketball player dribbles a ball.

Golfer hits a number of balls and finally gets the ball into the hole on the green.

Cartoon characters — Snoopy, Sesame Street characters, Disney characters, Warner Brothers' characters (Bugs Bunny, Porky Pig, Elmer Fudd, Daffy Duck). These must be relatively large if they are to be recognizable. Permission may be needed in some instances.

Caricature of politicians — These can be very entertaining but need to be built larger than many other lanceworks to be effective.

Cinderella — A fairy god-mother changes a pumpkin into an elaborately decorated coach.

Bee hive with bees — The hive is a lancework, bees themselves can be hummers from hummer candles or mines, or various Chinese whistle items such as "News Transmitters". The Chinese offer a number of small hummer devices. One is even called "small bees".

Green caterpillar becomes a colorful butterfly — Any number of designs for a caterpillar may work well. I have used the one pictured in Figure C-1. After about 20 seconds, the knobs on the antennae begin to spin (small wheels) and the legs move. After the caterpillar is extinguished, and the audience perhaps believes this is the end of the performance, a large butterfly ignites having colored and animated spots on its wings (wheels with color pots or color saxons).

Lawn Sprinkler Causes Flowers to Grow — Silver gerbs angled at about 45 degrees and mounted on a horizontal wheel, sprinkles the ground. (The gerbs used must have titanium or aluminum particles of sufficient size to reach the ground or the effect is lost). Lancework flowers are ignited while flat on the ground and then

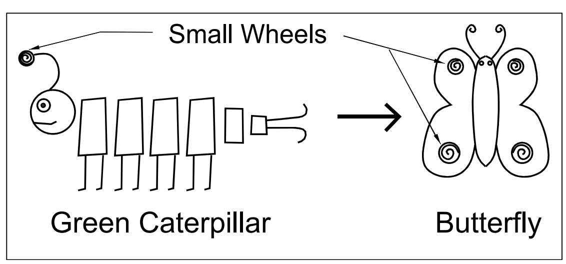

Figure C-1. Green caterpillar becomes a colorful butterfly.

pulled slowly into a vertical position. If this is done on a hillside, the flowers can be seen to grow out of a green field produced by green lances positioned on frames, which remain horizontal on the ground. There is danger of having the entire scene obscured by smoke because of too many lances being used at one time. If the scene is made very large and the green field is composed of widely spaced lances, the smoke can be lessened.

Duck, Egg and Duckling — A large white mother duck ignites, and about 20 seconds lager, a large white egg ignites below and behind her. After another 10 seconds, the egg forms a crack (a separate circuit ignites a set of lances forming the crack. These must be protected from igniting at the same time as the egg). After another 10 seconds, the egg splits open on a hinged frame and a small, "cute" yellow duckling ignites on a separate frame near the egg. The duckling is then "walked" across the field, at first away from the mother duck and egg, but then to a position immediately behind the mother (but not so close to the egg that it will be obscured). The motion of the duckling can be caused by simply having a black clad pyrotechnician pick up the frame, which initially rests against a couple of supports and with gloved hands and safety glasses "walk" the frame using a rocking and bobbing motion. This skit can be extremely successful in audiences having large numbers of small children.

Transformation Lanceworks — These are somewhat complex items in which a picture is embedded within another picture. Lances of two burn times are used (for example, 30 and 60 seconds). When the short lances become extinguished, a "new" picture comes into view. See *A History of Fireworks* by Alan St. H. Brock (1949), pages 223–226 and Plate XXII (facing page 192) for a description of transformation lanceworks.

Giant Firecracker — A large tubular firecracker sits at a 45 degree angle and has a yellow fuse that is about ♍ as long as the cracker, see Figure C-2. The fuse is composed of shortened lances, the shortest burning only 10 seconds and positioned at the far tip of the fuse. Progressively longer lances are positioned towards the cracker until several 30 second lances are situated immediately adjacent to the cracker's end. At the end of the 30 seconds, a large (preferably titanium) ground bomb explodes behind the frame severing a cord, which is suspending the upper half of the hinged firecracker frame. Thirty second lances must ignite at this same moment to produce the appearance of jagged broken ends of the cracker. The broken edges must not become ignited during the initial 30 seconds. The ground bomb must be suspended well above the ground so as not to throw debris and must be perfectly timed. I recommend it be done electrically. The shortened (cut) lances used in the fuse must be re-primed to insure ignition. The hinged frame must be carefully constructed to fall apart from its own weight but not to disintegrate into a crumpled heap on the ground.

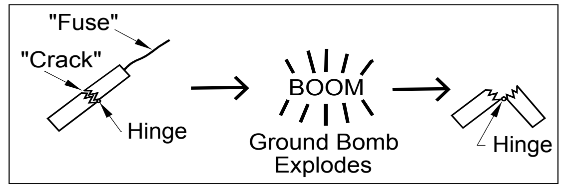

Figure C-2. Giant firecracker.

Human Face — This is one of my favorite ideas and although I have only had an occasion to use it twice, it has enormous crowd-pleasing potential, see Figure C-3. It consists of a large (the larger the better) round or oval face with changing expressions and moving pupils. Elaborations easily done include eyebrows for more expressive faces, hair (by use of carefully positioned multiple gerbs), and a movable mouth (using flexible hose or other suitable material). The eyes should be large and the pupils composed of three or more lances spaced about 2 inches apart in a triangle or other tight pattern. Expressions obtained with very simple lines include: happy, sad, sad with tears, "scary", dumb, very dumb, angry, ugly, vicious, surprised, quizzical, sly, disgusted (with a tongue), and sleepy (with half-closed eyelids). Moving eyes can be used with wonderful results. Small wheels can be used as eyes and can be made to spin in reaction to fireworks shot, or perhaps the ignition of an adjacent female face. Winking can be accomplished by having one eye on a revolving board that swings to face away from the audience and then back again towards the audience. (A strobe

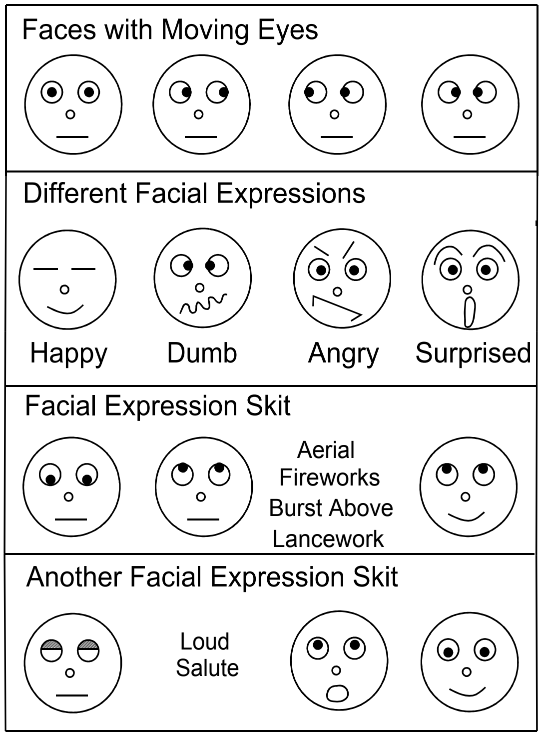

Figure C-3. Human Face.

pot might be effective to achieve a winking eye.) Skit possibilities are virtually endless. Very few pictures hold the attention better than that of a face. The human brain is very sensitive to subtle expressions and we have the propensity to see and make relevant even small changes in a face. The lancework designer should experiment with many drawings of faces in order to find appropriate ones that meet the needs of a skit. The drawings presented here represent only a few of the many possibilities.