An earlier version appeared in *American Fireworks News*, No. 65 (1987).

RAP* Shell Assembly Techniques

K. L. Kosanke

(* RAP stands for Rapid Assembly Plastic)

We have had a high degree of success using RAP Shells. Assembly times are a small fraction of what is required for Italian style construction and nicely symmetric breaks can be achieved when the proper techniques are employed. This article is a summary of successful methods used by us and reported to us by others. However, no attempt will be made to give detailed step by step instructions, nor will the information in our "Guide-lines for Assembling RAP Shells" [Copy follows.] be repeated here. While the information presented below is particularly relevant for RAP Shell assembly, much also applies to assembling other types of plastic and plastic/paper shells as well. To assist those readers who may not be familiar with RAP Shells, two figures have been included. Figure 1 shows the various RAP Shell components and how they are assembled, and Figure 2 shows a typically completed RAP Shell.

Solvent Bonding

It is certainly possible to apply the solvent for bonding the plastic components with a wool dauber. However, high quality breaks can not be reliably attained in this way. It appears that only by dipping one of the components into the solvent before assembling can high quality breaks be reliability achieved. Dipping is usually accomplished by filling a shallow tray with about ½ inch of solvent. Then one or more of the components are placed in the tray so that the surface where bonding is to be achieved becomes wetted by the solvent and starts to dissolve. The length of time the components should remain in the solvent depends on the

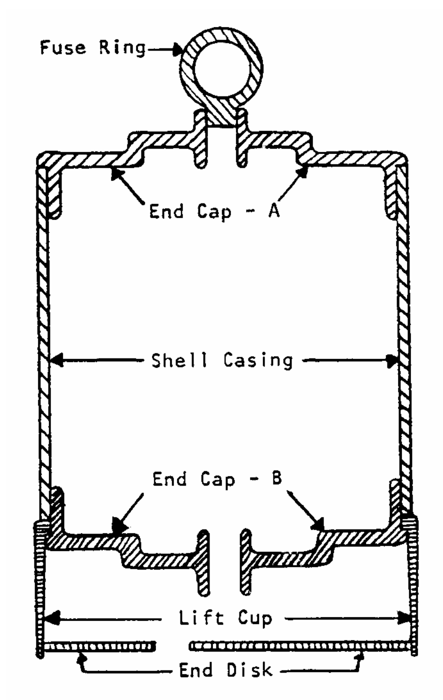


Figure 1. RAP shell showing component.

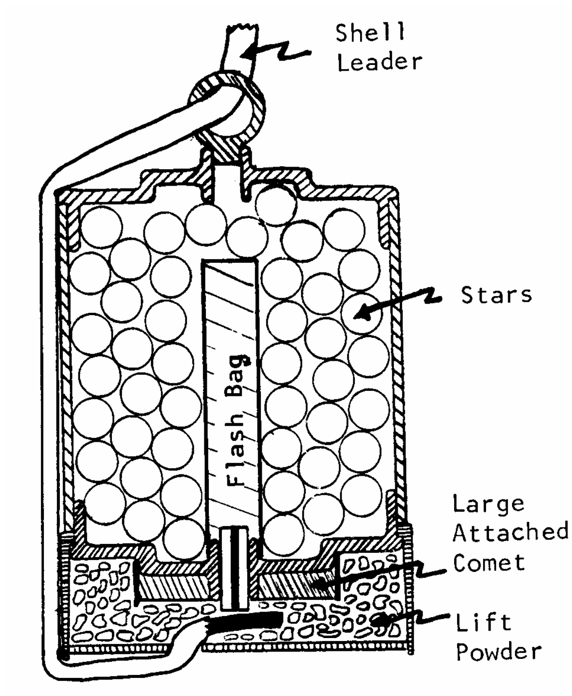


Figure 2. Typically completed RAP shell.

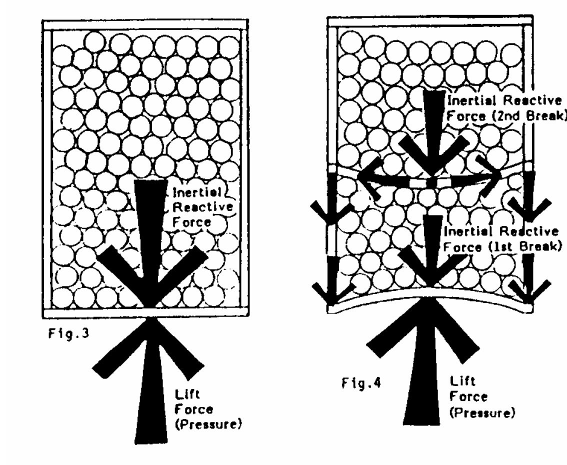
temperature and on the type of solvent used. (For methylene chloride, about 15 seconds is usually sufficient.) The dipping method has the added advantage of being easier and faster when assembly line techniques are employed. The disadvantage is that a larger quantity of solvent is initially required to fill the tray used for dipping. With a solvent such as methylene chloride, the rate at which solvent is used when dipping is not much greater than with the dauber. This is because methylene chloride vapor is about 3 times denser than air. Thus after the tray fills with vapor, relatively little continues to evaporate.

Caution When Using Thickened Methylene Chloride (TMC)

In the past we recommended the use of TMC when attaching the ring on the top of the shell that holds the quick match leader. (TMC is made by dissolving about 10% by weight of scrap polystyrene in methylene chloride, such that it becomes thick like a heavy syrup.) However, one person has reported having an unfortunate accident when using TMC. On opening the container of TMC the contents effervesced, frothing up to overflow the container (much like what sometimes happens with soda pop). When this happened his hands were covered with TMC. The methylene chloride caused a burning irritation of his skin, which was made worse by having to peel dried polystyrene from his hands after the solvent had evaporated. We have seen TMC effervesce slightly at times, though we have not had it froth up. We still use TMC but are more careful in its use.

Break Charge

Only through the use of high energy break charges have symmetric and broad spreading RAP Shell breaks been reliably achieved. Flash composition, whistle mix and perchlorate H3 powder have all been reported to generate high quality breaks of shells containing stars. Black Powder and pulverone have only been useful in breaking RAP Shells containing small self-propelled components. Formulations used in flash bags need to be slower and drossier than would be used to make salutes. (Guidance on the use of flash bags can be taken from the Oglesby article appearing in AFN #52.) Whistle mix (70% potassium perchlorate and 30% sodium benzoate) produces breaks as effective as with flash bags when the whistle mix was contained in a larger version of a flash bag in the center of the shell. When whistle mix is used but is dumped in loose, good breaks are obtained but not as reliably as when it is contained in a centrally located bag. Perchlorate H3 powder (70% potassium perchlorate and 30% airfloat charcoal) either granulated or heavily coated on rice hulls produces good breaks also.



Figures 3 and 4. Forces on shell.

Contents Loading and Break Symmetry

Because RAP Shells do not derive their strength from the careful loading of their contents, the stars and/or components can be dumped in loose. It is not necessary to attempt to consolidate them or even to fill the shell completely. However, it may be possible to achieve improved break patterns when care was taken to fill the shells completely full. Improved breaks may be more easily obtained when the length of the shell casings is equal to the diameter of the shell. ‘This also saves on the use of stars.) Finally, as with other types of shells, break symmetry is improved when the stars are loaded around a centrally positioned break charge.

Multibreak Shells

Some have reported the successful launch of multibreak shells (2 and 3 break color shells and color/color/report shells). However, I can not recommend this. In a conventional shell, much of the compressive strength of the shell is derived from the careful packing of its components. This is not the case for RAP Shells where the strength is derived primarily from its plastic case. On the one hand this has the advantage of not requiring careful packing of the shells. On the other hand it means that RAP Shells will not function very well to launch additional breaks. The reason for this will become more clear by examination of Figures 3 and 4. Figure 3 is a sketch of a single break shell being propelled upward inside a mortar. There is a large upward force created by the high lift gas pressure. This force is exerted uniformly across the bottom end of the shell, but to simplify the drawing and help illustrate the multibreak problem it is shown as a single large upward arrow. This lift force is opposed by an inertial reactive force (Newton's Third Law of Motion) in a downward direction. In essence this force is created by the stars' inertia (if at rest, the tendency to remain at rest) in reaction to the acceleration they are undergoing. These two forces are both acting on the lower end cap of the shell and to large measure, as far as the end cap is concerned, they balance each other. (They do not completely balance because there is also a small outward component of the inertial reactive force that is coupled to the shell wall by friction. However for the purpose of this discussion, this can be ignored.) Thus, for a single break shell, since the end cap has almost completely balanced forces applied to it, there is relatively little stress on it. Accordingly, the end cap can easily survive the lifting process. Figure 4 is a sketch of a two break shell being propelled upward inside a mortar. In this case the forces on the end caps are definitely not balanced. The inertial reactive force from the first break stars acting downward on the lower end cap only balances about half of the upward lift force acting on the end cap. In addition, the inertial reactive force of the stars in the second break is not properly balanced across the middle end cap. The stars push downward across the entire cap but are not opposed by a balancing lift force. It is the shell wall of the first break that communicates the inertial reactive force from the second break downward to encounter the lift force. The net result is that the bottom end cap experiences an unbalanced force in the upward direction and the middle end cap experiences an unbalanced force in the downward direction. Accordingly, much more strain is experienced by the end caps and there is a much greater chance of their breaking. RAP Shells were designed for a single break shell to have a good chance of surviving being 200% over lifted (three times the normal lift). However, they are not intended or designed to operate as multibreak shells.

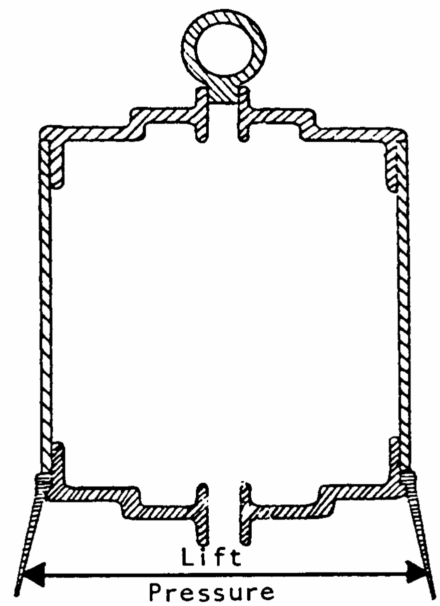


Figure 5. Lift cup expanding.

Lift Powder

Because of the design of the RAP Shell lift cup, less lift powder can be used than is necessary for conventional shells. (See Figure 5 to see how the lift cup expands to close the space between the shell and mortar, much the same way as the wadding acts in a shotgun shell.) We use 0.6 and 1.1 ounce of powder to lift 3-inch and 4-inch shells, respectively, which contrasts with 1.0 and 2.0 ounces for conventional cylindrical shells. Also there is no difference in the lift achieved when using 2F powder as compared with using 4F powder. (Normally small shells are propelled more efficiently with 4F powder.) This means that there is no cost advantage in using 4F powder, and the more gentle 2F powder can be used. Some hobbyists, for whom it is difficult to obtain commercial Black Powder, have reported success using granulated perchlorate H3 powder. Also success has been reported using granulated handmade meal powder (75% potassium nitrate, 15% air-float charcoal, 10% sulfur, and +5% dextrin) mixed with a small amount of sporting grade Black Powder (to speed up the burn of the handmade powder).

No RAP Salutes

We have had reports of people using RAP Shells to make salutes. We strongly recommend against this practice. While RAP Shells are made of high impact polystyrene, they are still somewhat brittle and when shattered (broken explosively) sharp fragments will be produced.

Caution with Paper Mortars

In our testing of randomly selected normally lifted RAP Shells we have test fired hundreds of RAP shells, and have never experienced a flowerpot (shell failure inside the mortar). However, when using RAP Shells in our commercial displays we observed several percent of the shells to flowerpot. This was puzzling because it was the same shells that never failed during tests, that occasionally failed during displays. The problem was traced to our paper mortars, which had seen a moderate amount of use and were slightly torn on the inside surface. They were still successfully launching spherical shells but were causing cylindrical shells to occasionally jam when fired from them. (In our testing only steel and high density polyethylene mortars, with smooth interiors, were used.) RAP Shells do have a rounded upper edge, but no where near so rounded as a spherical shell. Thus, if paper mortars are to be used successfully, they must be inspected and damaged mortars must not be used.

Conclusion

I have been surprised by how quickly and effectively people have learned the new technology of plastic shell construction. RAP Shells can be assembled in a small fraction of the time required for paper/string shells and they can be made to perform approximately as well. I am certain that, of the shells made in this country, plastic shells will become the most frequently made shells in the future. Hobbyists can easily make effective shells and professionals can increase their narrow profit margins. In fact, because of improved fire safety (the lack of burning fall-out) some countries (e.g., France) are reported to have banned the use of any aerial shell NOT made entirely of plastic.

An earlier version appeared in *American Fireworks News*, No. 72 (1987)

Destructive Testing and Field Experience with HDPE Mortars

Ken Kosanke

In an earlier article on High Density Polyethylene (HDPE) mortars, results from an initial series of tests were published (*Pyrotechnics Guild Int'l. Bulletin*, No. 54, p 5). Those results will not be repeated here. This article continues by presenting the results from an additional test, a summary of the author's field experience since the first article, and comments on HDPE mortar use in England by Rev. Ron Lancaster.

Destructive Mortar Tests

Three tests were performed in which a 22" long 3" diameter HDPE mortar (SDR = 13.5, resin type PE3408) was staked above ground and a 3" salute was exploded in the bottom of the mortar. Approximate determinations were made of: 1) the percent weight loss of the mortar due to fragments leaving the mortar, 2) the radius and area through which fragments were found to have been propelled, and 3) the shape and weight of typical fragments. In the three tests, the mortars were at three different temperatures (5, 40, and 80 °F); however, no temperature dependence was observed in these very limited tests. On average, 6% of the mortar's weight was lost as fragments (not counting the loss of the wooden mortar plug). The fragments were found to have been propelled to a maximum distance of approximately 100 feet, which corresponds to an area of about 30,000 square feet. A typical fragment was stretched to about 1/3 its original thickness, was roughly leaf-like in appearance, and weighed about ½ ounce. Judging from the shape and weight of the fragments, it is estimated the serious injury to a properly clothed and positioned shooter, even if struck by one of the few fragments, was unlikely.

As a comparison, two similar tests were performed using 24" long 3" diameter PVC mortars (Sch. 40). In this case, nearly the same range of mortar temperatures were used (10 and 80 °F). As above, no temperature dependence was observed. On average, 80% of the mortar's weight was lost as fragments. Those fragments were frond to have been propelled to a maximum diameter of approximately 175 feet, which corresponds to an area of about 100,000 square feet. A typical fragment retained it original thickness, had sharp edges and jagged points, and weighed one or two ounces. Judging from the shape and weight of the fragments it is estimated that serious injury to a properly clothed and positioned shooter was likely if struck by any of the large number of fragments.

The stretching thin of HDPE mortar fragments causes them to be slowed more rapidly after being thrust into the air from a bursting mortar (they are more like a feather than a rock). However, this stretching has an additional safety benefit. The mechanical energy that is consumed in thinly stretching the fragment is, in the process, converted into thermal energy, raising the temperature of the fragments. Calculations suggest that the stretching will result in a temperature rise of about 40 °F. The HDPE fragments are somewhat flexible to begin with, but they become more flexible as their temperature rises.

From these limited tests, it seems fairly clear that HDPE mortars present less danger to nearby persons and equipment in the event of a shell detonation within them, than PVC mortars similarly stressed.

Limited Field Experience

During the recent season, HDPE mortars were used by the author on four displays in which approximately 800 three to six inch shells were fired. (The equipment used to fire the shows positions the mortars in very close proximity to each other in steel racks. The so-called dense-pack set-up was described in a