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Troubleshooting...

Shell Lift Failures

Introduction:
Of the two general classes of shell failure that can occur, during lift and during break, it is the lift failures that are the most disappointing. Nothing is worse than spending many hours building a complex shell only to have it flowerpot out of the mortar. This often leaves one thinking "I could have achieved the same effect in much less time by just throwing all the components into a sandwich-bag mine!" As such, there is usually the feeling of great relief when any large or labor intensive shell makes it out of the gun with its lit spolette spiraling through the air!

This article examines some of the most common causes of lift failure for both round shells and canister shells.

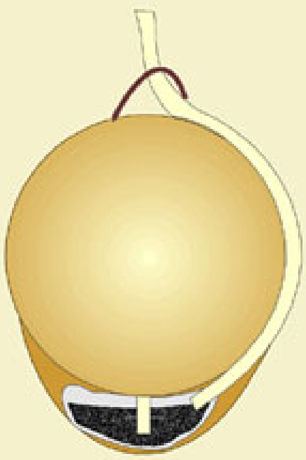

Figure 1: Placing the lift charge in a plastic bag to reduce the potential for water damage.

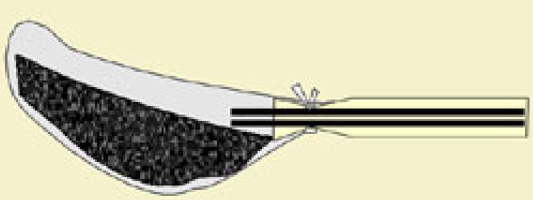

Figure 2: Multiple strands of black match allow central air gaps in the pipe, protecting against fire blocks caused by pipe constrictions.

Ingnition Failure:
This type of failure occurs when the shell fails to fire after it is lit.

Wet or Damp Lift Charge - mortars stored outside often have water in the bottom of them, which quickly absorb into your paper shell and ruin your lift charge. Rain that occurs after the shell has been loaded can be equally destructive. This type of failure can be protected against to some degree by loading your lift into a plastic sandwich bag prior to installing it into your shell. Some builders and commercial manufacturers will bag the entire shell in plastic to protect against standing water or rain that occurs after a shell has been loaded.

Wet Leader - paper quickmatch leaders can also absorb water and transfer it to the black powder strands inside. This is usually caused by rain, but in some cases the black residue inside recently fired mortars can work its way into the match pipe of snug fitting canister shells. While quickmatch is pretty resistant to failure caused by dead spots in the fuse, certain circumstances will still cause failure. Some brands of commercial quickmatch now have a plastic wrapper on the outside in order to prevent this type of failure.

Choked Leader - if the quickmatch pipe is constricted around the blackmatch strands so tightly that air can not easily flow pas the constriction, ignition failure can occur. This can happen when

Figure 3: Securing leader with two separate ties instead of one.

tying the leader into the lift bag if the string is pulled too tight, especially if only one strand of blackmatch is used inside. The problem is considerably less likely if more than one match strand is used inside the pipe. Using multiple strands of blackmatch when making your own quickmatch is recommended to avoid ignition problems in general, even when no constrictions exist.

Pulled Leader - this cause is more common with canister shells and results from the temptation to use the match leader as a rope for lowering the shell into the mortar. Depending on how the fusing is done, several failure types can result from pulled or partially pulled leaders caused during loading. Preventive measures include 1) securing the leader with two separate ties around the shell wrapper, spaced a few inches apart 2) using waxed linen twine when tying blackmatch over spolettes 3) using virgin kraft if rolling your own match pipes and 4) avoid using shell leaders to lower shells weighing much over a few pounds.

Of all the things that can go wrong, ignition failures are about the only type that can be repaired, since the shell is left intact. Extreme caution must be used however, since a live shell that has had fire on the powder train now sits in the bottom of the mortar in an unknown state. Allow several hours before attempting to remove the shell, as small "cherries" of nitrate-soaked string can smolder for unpredictably long periods of time before unexpectedly bridging dead spots in the black match and firing the shell. The shell should be removed by pulling the mortar and dumping the shell from it without ever placing any body parts into the would-be trajectory should it fire.

More...

Shell Lift Failures...

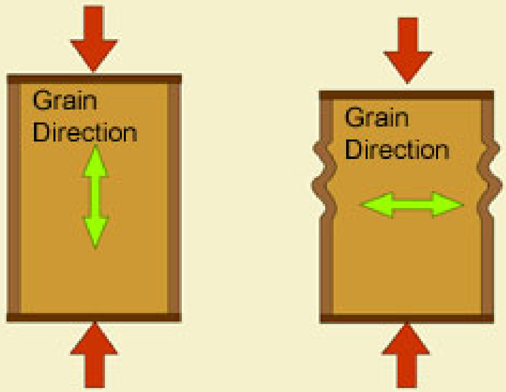

Figure 4: Compression resistance relative to paper grain direction.

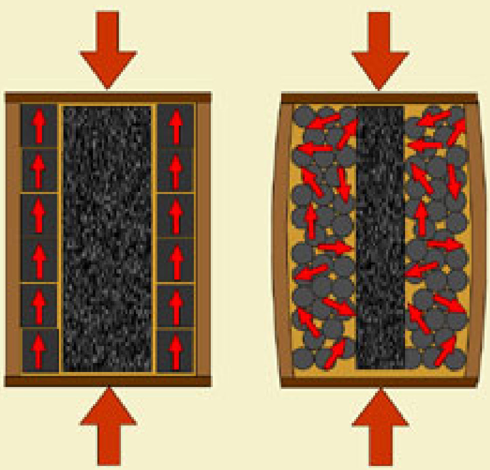

Figure 5: Internal force transfer vectors for stacked comets compared with round stars in a shell compressed during lift.

Flower Pot:

This is the term given to the type of failure where the shell explodes in the mortar.

Gas Leak - if there are any open pinholes around the time fuse or defects in the pasted outer casing, the high pressure gases generated before the shell leaves the mortar can get inside the shell and set it off. With paper ball shells this type of defect is very rare, but with plastic ball shells it is more common. Plastic shells can have small cracks in the seams where the hemispheres are glued together, or pin holes around the time fuse where it is glued in place. Care must be taken to glue plastic shells together with a solid bead of glue to avoid this.

Canister shells that are bottom fused, meaning the time fuse faces the lift charge when the shell is fired, are more susceptible to flower potting due to gas leaks around the spolette. Unlike ball shells, which have a rounded surface to direct the lift gases around the fuse, not to mention a considerable amount of pasted paper around the time fuse, the ends of a canister shell are flat and thus exposed to more pressure per square inch. For this reason all but small single break canister shells are generally top fused.

Split Shell Wall - this type of defect can occur with larger canister shells that are either not loaded with stars properly or were rolled with the paper grain in the wrong direction (or both). Because the lift force builds so quickly under the shell, which is at rest, the effect is like smacking the bottom of the shell with a sledge hammer. The more mass the shell has, the more it will be subjected to compression forces before it starts to move. If the shell does not have the structural integrity to handle such compression forces, the shell will actually compress. This compression will cause the side wall to split and expose the contents to the hot lift gases, thus bursting one or more breaks in the mortar.

The longer and heavier the shell is, the more it is susceptible to this kind of failure. For a multi-break shell, the lowest break on the chain experiences the most compression, since it has the weight of the other breaks above it. Longer individual breaks are also more prone to compression than shorter ones when all other variables are held constant.

There are three basic measures you can take to reduce shell wall failure on canister shells. For large multi-breaks, every precaution available needs to be taken:

1) Stronger Casing - this means using thicker paper, more turns of paper and rolling with the grain aligned parallel with the length of the shell. A paper tube with the grain direction running circumferential to the tube is more compressible than one where the grain runs end to end, as illustrated in Figure 4. Think of the paper grain as tiny support columns. You want the columns running from top to bottom, not stacked on their sides. The goal is to make a casing that is as resistant to compression as possible.

2) Solid Internal Loading - even a strong case will still compress if the internal contents do not form a solid column of support inside the casing. Loosely loaded round stars are the poorest choice for internal support, while cut stars are more supportive and stacked pumped stars are the most supportive.

To visualize how different star geometries provide various degrees of structural integrity, imagine a paper lunch bag packed solid with similar shaped objects. If you stomp on a bag filled with round marbles, the bag will easily split and spew the marbles out the sides. If the bag is filled with square dice, it will not split as easily but still may rip slightly or require a harder stomp. If equal sized Lego blocks were stacked on top of each other to form a square brick wall, the bag would not split at all and you could put your full weight on it.

It is for this reason that large multi-break shells require pumped stars or cylindrical inserts to be stacked on top of each other in rings. An 8" multi-break filled with loose cut stars would not be able to withstand the crushing force, just like the bag of dice splits open in our analogy. Also note that any inserts used inside the shell must each be solid themselves, since the compression force will be transferred to everything inside the shell. In the case of large shells that must contain weak inserts, such as plastic lampare containers, additional support must be added inside the shell such as wooden dowel rods or very strong paper tubes that will keep the compression forces from crushing the fragile inserts.

In addition to the correct choice of internal components, any air gaps between and above the shell contents must be filled with a solid material such as pulverone or sand, otherwise the resulting air gap would allow the shell to compress and rupture.

3) Shock Absorption - since the compression force results from the rapid buildup of pressure over a very short period of time, another approach is to soften the impact with a less aggressive lifting mechanism. This involves using some kind of intentionally compressible material (crumpled wads of paper or cloth) between the shell and a piston plate placed above the lift chamber. As the piston plate rises, the material between it and the shell will compress, resulting in a slower transfer of lift force onto the shell. The Maltese employ this method to great effect, along with additional compressible material placed between each break of their large multi-break shells.

Crushed End Disk - this is similar to split shell wall, except the bottom of the shell casing caves inward instead of the side splitting outward. This is more common on larger diameter canister shells where the end disk has to span a larger area. Because the end of the shell is not curved, it is inherently weak and vulnerable to outside pressure caving it in, especially since the bottom disk takes the full brunt of the lift force.

This problem can be remedied by using multiple end disks stacked on top of each other to make a stronger disk. Applying glue between the disks will add considerably more resistance to bending compared with loosely stacked disks. Stronger material may also be used for the disk, such as kraft disks instead of chipboard disks. All the methods of internal loading mentioned above are also important for preventing the end disk from flexing inward. The Maltese shock absorption piston method of lifting shells also removes the crushed end disk problem completely.

Break-ups - long multi-break shells can actually split apart at the junction between two breaks as the shell leaves the mortar. It is quite common for the spolettes on each broken piece to take fire and operate normally on the way up, with the gaping hole left on the bottom of the top piece somehow mysteriously avoiding ignition. This phenomenon has been witnessed many times both in the US and in Malta, so there is more to it than a freak incident but nobody can really explain how it occurs. My guess is that the Bernoulli effect pulls a vacuum inside the shell as the air rushes past the open hole, thus preventing any hot gases from getting inside. This same effect has often been blamed for "sucking" the fire out of burning spolettes right at the moment of flame transfer to the burst charge, thus leading to the development of the conical spolette rammer.

The suggested cure to this type of malfunction would be more vertical strands of twine holding the breaks together, using stronger twine and/or pasting the shell in with more turns or stronger paper.

Passfire Failure - this is actually a type of ignition failure on a canister shell whereby the passfire down the side of the shell fails after the top spolette has already taken fire. The result is that the first break flower pots in the mortar, usually setting off the lift charge at the exact same time and sending the remaining breaks skyward. On very long shells the passfire often doesn't actually fail, rather becomes delayed due to constrictions while trying to get to the lift charge. The length of the hang-fire delay determines weather the failure is a flowerpot or a first break going off dangerously low.

This type of problem can be dealt with by using only the highest quality black match as your passfire link, or even making two separate side-by-side passfire links if you have the mortar clearance to permit this. Avoid constricting the passfire pipe in any way, and don't use twine to tie off the end or pinch it closed in any way. The more breaks your shell has, the shorter the first spolette delay will be and thus the more critical it is that the shell fires at the same time this fuse ignites. Even small passfire delays on a large multi-break can cause nasty low breaks.

Conclusion:

These are the most common causes and cures for shell problems that occur during lift. Since flowerpot failures typically destroy all the evidence, it can be difficult to ever know exactly what caused the problem. Gas leaks, shell ruptures and disk failures all have the same end result, so you are left to analyze the shell construction from memory and draw your own conclusions. But keeping these basic principles in mind, along with experience and attention to detail, will greatly reduce your CATO statistics!