Steel Shot: what you need to know

Part 4: Budget loads and matching pellet weights: the cost in price and performance.

21gram Lead shot cartridge components

24gram Steel shot cartridge components

In part one of this series we saw that steel pellets are much lighter than lead for any given size so there are more of them in a given charge of shot. In part 2 the implications of the relative lack of momentum with steel shot was seen to be an issue with regards ricochet potential. In part 3 the choke issue was raised along with other ballistic anomalies that are exacerbated with steel pellets. In part 4 the potential cost savings and the real world situation regarding target breaking power downrange with steel pellets are considered, together with the practical limitations of steel pellets that fall within the size limits currently imposed for clay pigeon shooting.

Price considerations

As most steel shot cartridges would appear to be bought on price grounds (except where lead shot cannot currently be used, such as where spent pellets might fall within the boundaries of an SSSI), the best comparison would seem to be with the cheapest club level budget lead shot cartridges. Only plastic wadded lead shot loads were considered, as shooting grounds that allow the use of steel shot must by inference also allow plastic wads. A scan through the cartridge retailing websites revealed that while lead shot loadings are as a rule more expensive, it is possible to get much closer in price to the cheapest steel loadings that might have been thought.

How much is really saved with steel pellet shells?

A price comparison was made and (25 10 11) the cartridge costs are listed together with their savings and the saving per box of 25 when bought at the 1000 rate. All of the retailers stated on their websites that the prices were subject to change without notice.

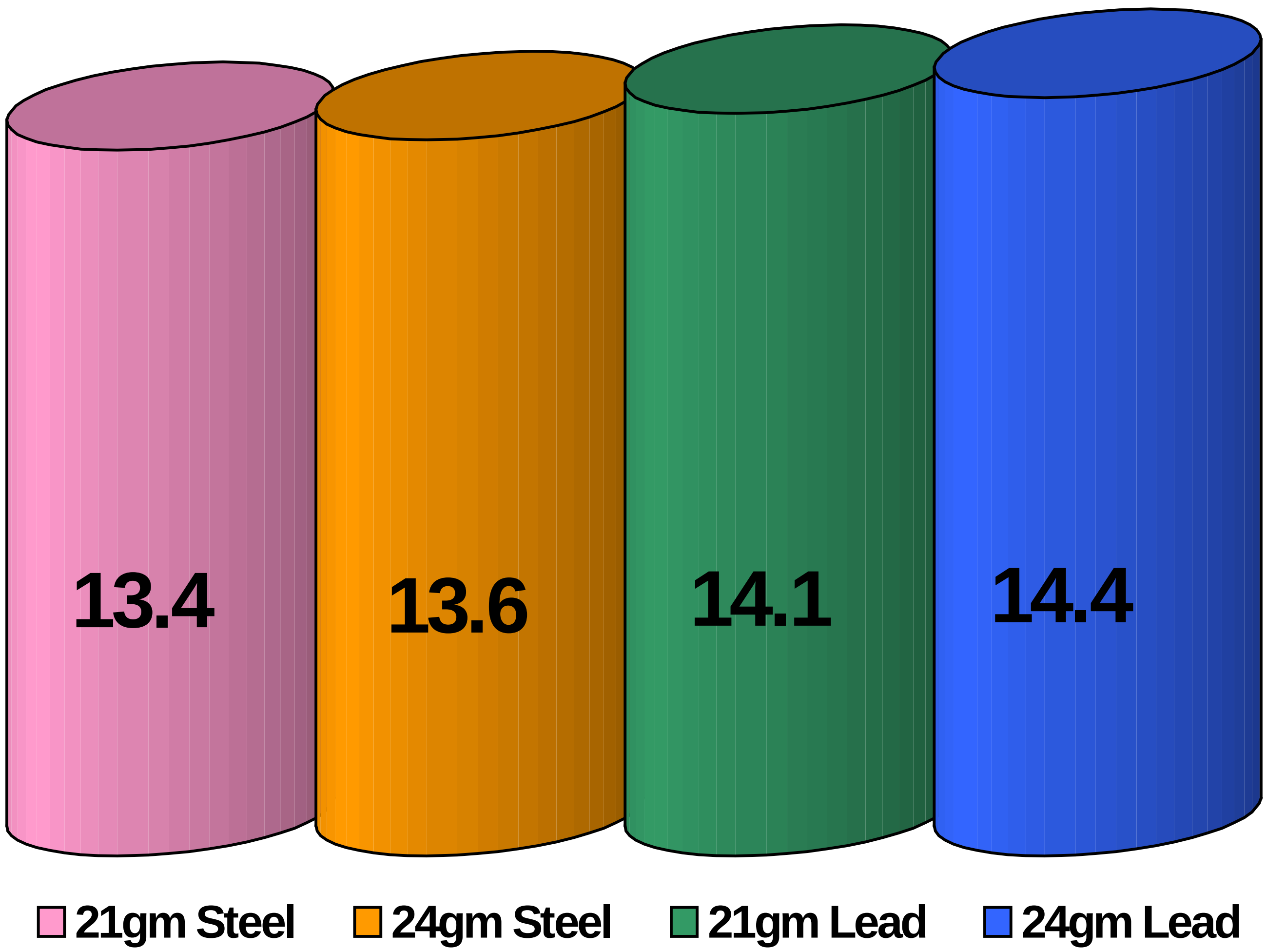
The cheapest Lead 21gm cartridge was listed at £141.25 per 1000,and the cheapest steel loading was a 21gram version at £133.50 per 1000: this is a saving of £7.75 per 1000 (19,5 pence saving for a box of 25).

These 21gram steel shot loads were the cheapest 12bore cartridges that could be found on the website listings.

The more popular 24gram steel loads were listed at £136 per 1000, with the cheapest 24gram lead shot shells being £144 per 1000: a saving of £8 per 1000, (20pence saving for a box of 25).

A more realistic comparison and one that better represents what is actually going on at the shooting grounds, would be between the steel 24gm(£136 per 1000) and the lead 21gram (141.25 per 1000) loadings; here the saving is less distinct at £5.25 per 1000 (13 pence saving per box of 25).

Chart1. The cheapest individual cartridge cost (in pence each) when bought at the 1000 rate for both Lead and Steel shot 21 & 24gm budget loadings (25 10 11)



In this case this additional cost for 25 lead shot 21gram cartridges is akin to needing an extra cartridge because of a single no-bird in a round of 25 targets.

Clearly the exact savings with certain types of cartridges will vary, but it must be said that a larger saving was expected with the steel loads. Cost alone was the criteria in this instance, but of course the other issue is whether an individual shooter gets on with the particular cartridges chosen, but this is another matter.

Buying in larger quantities than 1000 cartridges can also give greater savings, but most clay shooters do not do this.

The cost in downrange performance

We briefly touched on the problem of same sized pellets for both lead and steel in part one, of this series.

Here we are comparing the budget steel and lead loadings, where the lead pellets tend to be the denser (2% antimony content) variety.

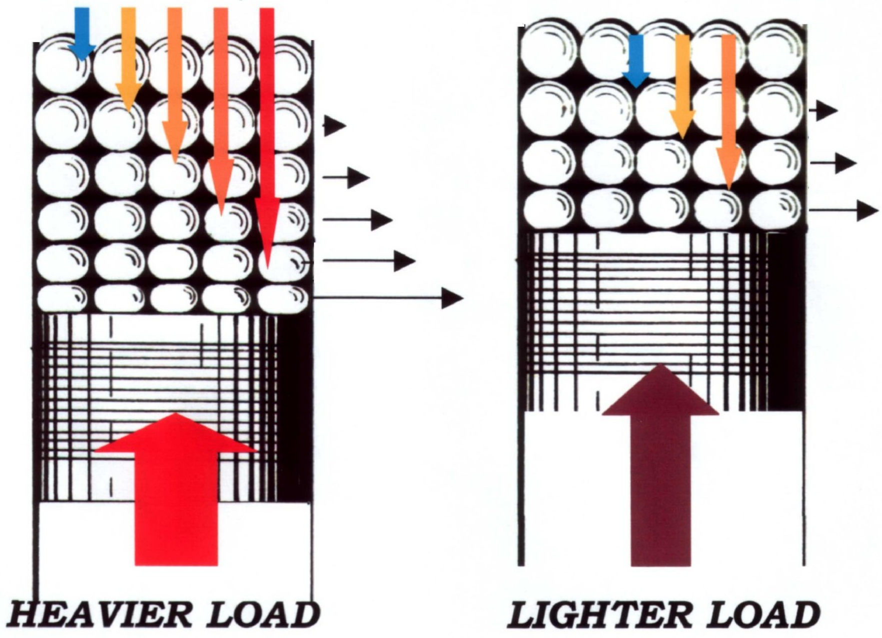
In top of the range lead pellet loadings with heavier payloads of up to 28grams, the harder type of lead shot (5% antimony content) tends to be used with its slightly lower density.

If a typical loading of UK 7 shot is considered the difference in the actual pellet count with a 28gram loading Is not massive (about 12 pellets*), but it can be significant in other ways.

***28gram with 5% antimony has about 343 pellets of UK 7, with 2% antimony this drops to around 331.**

PROGRESSIVELY INCREASING DOWN THRUST FORCES SHOWING THE INCREASED DISTORTION OF THE SHOT WITH A LONGER COLUMN

FIGURE 1



The downrange velocity retention of these slightly fewer but denser lead pellets is greater, as long as they are still in reasonable shape and do not fly erratically.

This is their main bugbear, as the heavier the loading and the larger the pressure behind them when fired; the greater will be their tendency to distort.

This distortion tends to work on the

lower layers of the lead pellets far more than the top ones, (see figures 1 and 2).

This is why top-level competition clay pigeon cartridges were historically loaded with the hardest lead shot types. With the heavier 32gram (1,1/8oz) loadings that were almost universally used for clay pigeon shooting, this was a necessity, especially for the demanding sports of Olympic Trap and Skeet, together with the use of plastic wads. This was even more of an issue with the 36gram (1,1/4oz) 'monsters' that were allowed for International FITASC sporting clays until relatively recently.

FIGURE 2

Heavier lead clay pigeon loads are generally less efficient, because they damage a greater percentage of their pellets with their much longer and taller shot columns. The now defunct 36gram FITASC loadings had to use the hardest (5% antimony alloy) lead shot to help combat this.

The trend in the dropping off in competition payloads is best demonstrated by the Olympic Trap and Skeet disciplines. They have dropped right down to 24grams, 25% less than the old standard clay pigeon 32gram loads.

The much shorter shot column and higher efficiency of the 21gram 12bore cartridges is quite remarkable, as they can be surprisingly effective downrange even with 2% antimony shot, as well as being easier on the pocket.

Lighter lead loads have less distortion

The main villain of the piece with lead shot is the length of the shot column for any given load weight.

The larger numbers of pellet rows in a higher and longer shot column massively increase the pressure upon the lower level pellets.

The ultra light 21gram 12bore loadings have very much shorter shot columns than any previous clay pigeon cartridges. As a direct consequence of this and lower breech pressures, a much greater percentage of their pellets are capable of surviving in good condition. They can then go on to make excellent quality patterns downrange when loaded sympathetically and fired at normal velocity levels.

Hard steel

Due to its much greater hardness than lead, steel shot does not distort from its original shape to an appreciable degree, at least not once it has left the confines of the barrel. Its elastic properties allow it to bounce back into shape, even after being forced through overly tight chokes (see part 3 of this series for the full details).

The flight of steel pellets does however depend on their quality and general roundness. Any significant imperfections can cause it to meander off of its intended target direction to a greater degree, slowing down more quickly than the more perfectly round steel pellets.

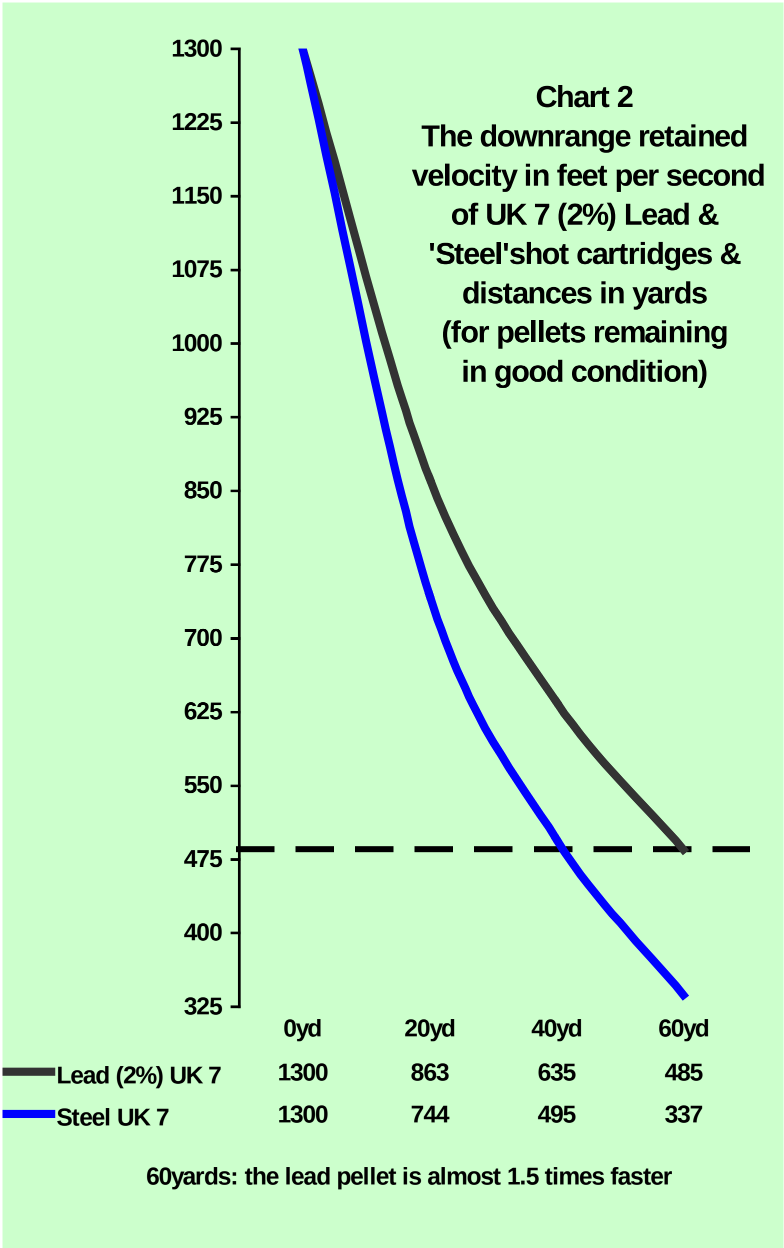
The advantage of hardness is somewhat countered by steel's lack of density, which puts severe limitations on its downrange potential.

Comparisons will be made of the effectiveness of 21gram lead and steel 24gram cartridges, but first the issues of velocity, density and pellet size must be considered.

Lead and Steel pellets compared

The two charts showing the comparison between the same sized (UK 7) pellets of both steel and lead amply demonstrate that density is a serious factor that is an absolute requirement for effective downrange performance.

Charts 2 and 3 show the retained velocities and pellet striking energies with steel and lead (2% antimony alloy) UK 7 (2.4mm) pellets as the range increases.



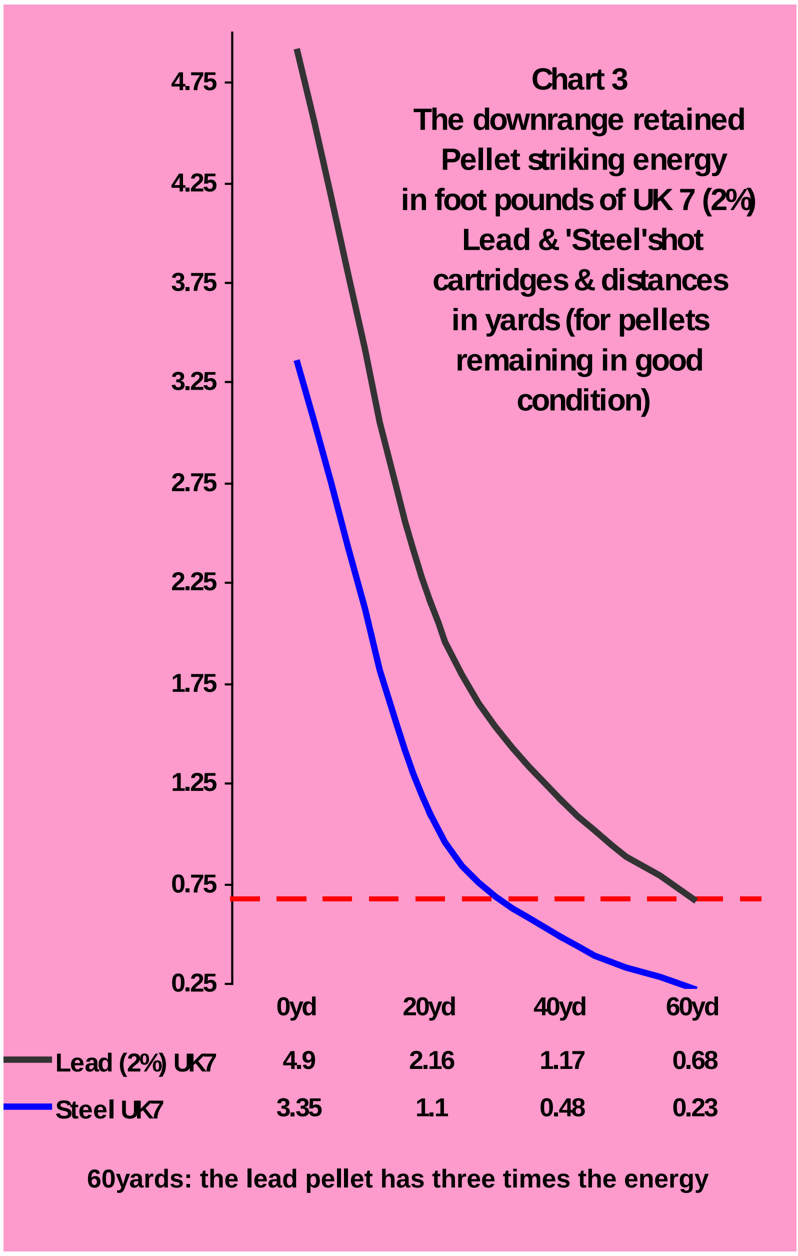


Chart 2

This shows the increasing 'drag' on the steel pellets' velocity by the air resistance. Its inability to retain velocity is a direct result of its lack of density.

It can bee seen that the lead pellets' velocity at 60yards has dropped down to 485 feet per second, the steel pellets' velocity matches this at a exactly 41yards(485fps); only two thirds of the distance achieved by the lead pellet for an identical velocity drop.

This drop off in velocity at distance exactly matches the ratio of the pellets' densities. This means that because the steel pellet has only 68.35% of the weight of the Lead 2% pellet, for the same velocity drop off (as the lead pellet), this will be only 68.35% of the distance in yards; 41yards is exactly 68.35% of 60yards.

Clearly the lack of pellet density (or weight if preferred for any given pellet size) plays havoc with the retained downrange velocity potential.

The number 7 UK steel pellet has the same sized path to cut through the air as the lead pellet, but it has much less weight behind it to be able to do so as effectively.

Simply put, the heavier (denser) a given pellet is for its size, the better it will retain velocity.

Chart 3

The rapid drop off in velocity by the steel pellets as shown in chart 2 is disconcerting, but when the steel pellets' lack of weight is also considered, this makes for a much bigger drop off in striking energy than the velocity drop alone. Striking energy is a combination of pellet weight and velocity, but as the velocity increases, the striking energy rises at a much higher rate.

An example of this is a lead (2% antimony) shotgun pellet travelling at two different velocities.

At 1000fps it has 3ft/lbs of striking energy, but at 500fps it has only 0.75ft/lbs.

The faster pellet has twice the velocity, but four times the level of striking energy.

So the more serious shortcomings in the matter of striking energy are exposed by the lead pellets' 60yard energy levels (0.68 foot pounds), being only matched by the steel pellet at a lowly 31.2yards, or almost exactly half that distance.

It must be appreciated that when the same sized lead and steel pellets are travelling at the same velocities, the striking energy of the steel pellet can only ever be 68.35% of the lead one, because it only has 68.35% of its weight. There is clearly no way that the steel number 7 pellets can compete with the lead ones at longer distances for efficient clay pigeon breaks; same size lead and steel pellets simply cannot work.

Matching up pellet weights with steel and lead

One approach to attempt to mitigate the downrange losses incurred with steel pellets is to match up the pellet numbers, (and therefore their weight) in any given loading. This might seem to be an entirely reasonable approach when it is first considered, but the main drawback with matched pellet weights, is the necessarily much larger size of the steel pellets, incurring higher levels of velocity sapping air resistance to their flight. As there are now equal numbers of pellets, the increased size of the steel ones also causes problems with their volumetric capacity, or simply the space that they must take up within the cartridge casing.

The practicalities of the volume problem

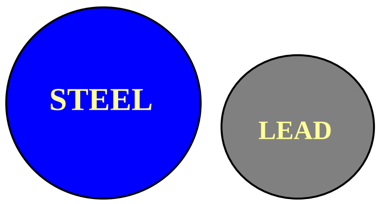
Because there are identical numbers of them in the load, the unavoidably greater volume of the larger and less dense steel pellets must take up more room within the confines of the loaded cartridge.

What this means is that even though both the lead 9's (2.03mm) and the steel 7.5's (2.3mm) can weigh the same, a 21gram load of steel 2.3mm pellets will actually take up as much room as a 2.3mm lead pellet loading of 30grams.

With the maximum 28gram loads UK 7.5 (2.3mm) steel pellets can take up as much room as 40grams of lead UK 7.5 pellets. The absolute limit with currently allowable C.I.P. velocities and the available powders and other components for the small to medium sized steel pellets in the 70mm cartridge case with its star crimped closure is 32grams.

Figure 3

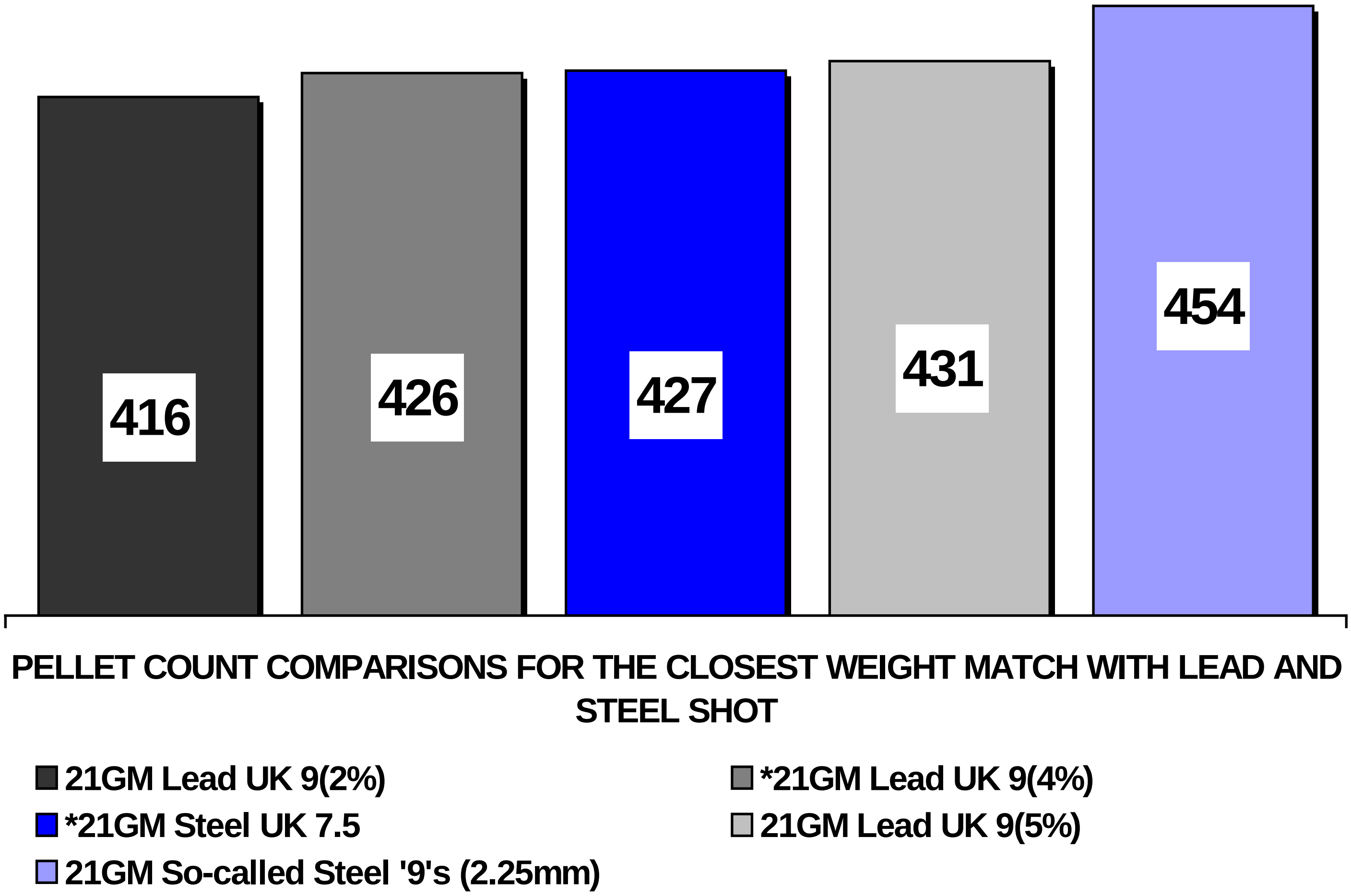
Matched pellet weights



Matching up lead and steel shot pellet weights and therefore their Numbers in any given load, requires a lot more room inside the cartridge to accommodate the much larger volume taken up by the steel pellets.

The pellet weight matches available within the allowable shot sizes for clay pigeon shooting that are used in the UK are shown in chart number 4.

CHART 4



The closest possible pellet match for an accurate assessment is UK lead 9 (2.03mm) with a 4% antimony (and other hardening agents) alloy and steel UK 7.5 (2.3mm).

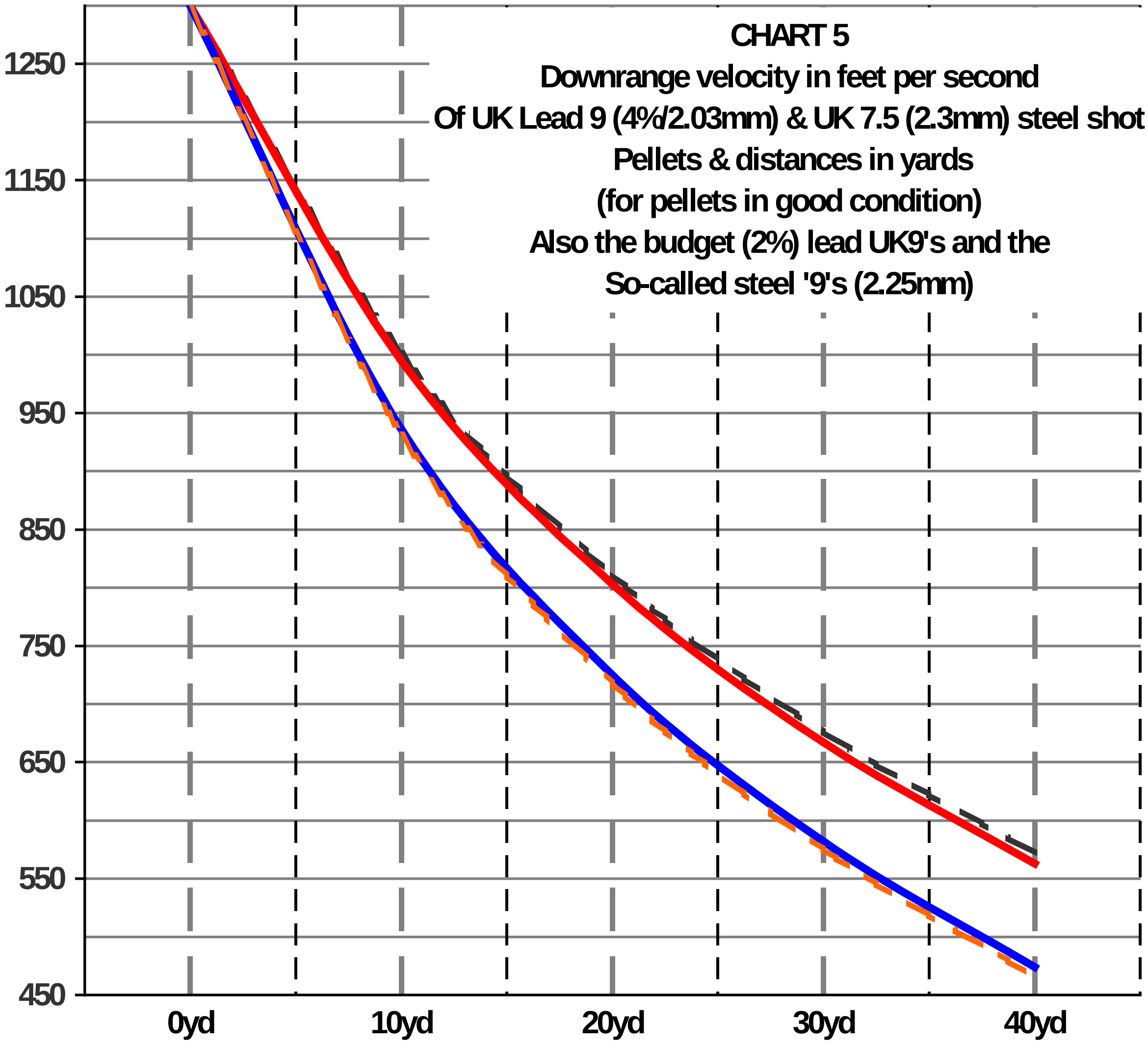
The reason that the UK 9 lead pellet types vary in pellet count, is because their hardening agents (such as the percentage of added antimony) are much lighter than lead, so the greater the content of hardening agents, the higher the number of pellets per load.

When compared with the steel UK 7.5 (2.3mm) pellets, the budget lead loads (with 2% antimony lead alloy) of UK9 shot (2.03mm) have a slightly lower pellet count, but the harder top of the range types of UK9 (with 5% antimony lead alloy) have slightly more pellets.

Comparing the downrange potential of same weight pellets in both lead and steel

Chart 5.

The solid lines show the downrange velocity retention capabilities of lead UK 9 (2.03mm) with 4% hardening agents and steel UK 7.5 (2.3mm) pellets of the same weight. The dashed lines also show the budget (2%) lead UK9 and the so called steel '9's (actually 2.25mm maximum diameter) that are found in some steel shot skeet loadings.



	0yd	10yd	20yd	30yd	40yd
Lead (2%) UK9	1300	1001	811	676	572
Lead (4%) UK9	1300	995	803	667	563
Steel UK7.5	1300	936	725	582	474
Steel '9' 2.25mm	1300	931	718	575	466

The considerable velocity sapping forces of air resistance are not to be taken lightly, as even when both the steel and lead pellets are the same weight (in this case two shot sizes larger), the larger diameter of the steel one has a much rougher ride and loses velocity much faster.

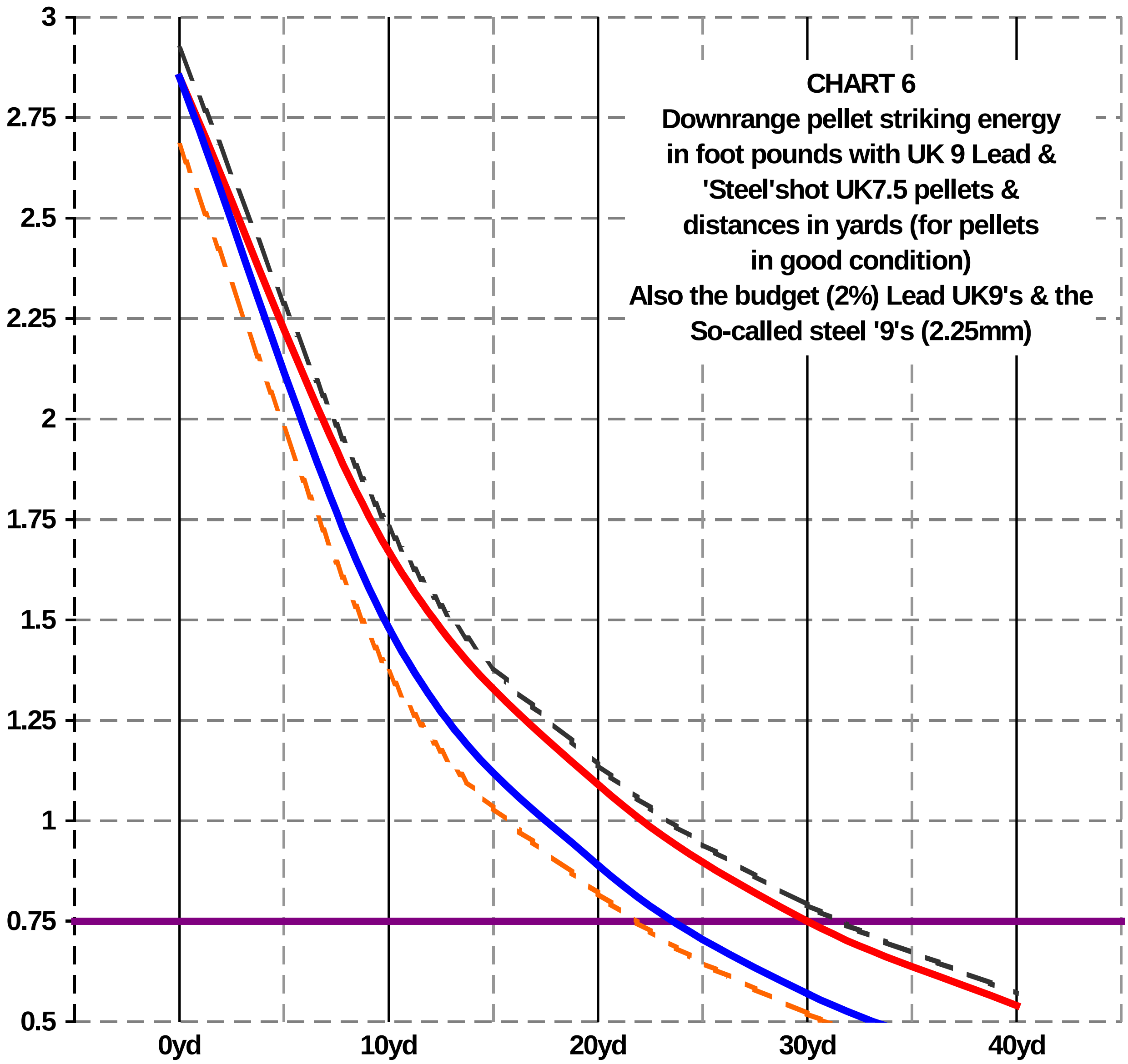
We can see from chart number 5 that even by 20yards, the slowing down of the steel UK7.5 by the resistance of the air to its flight, has already significantly taken place, as the lead UK9 (4%) pellets are 11% faster, at 30yards and 40yards they are 15% and 20% faster respectively.

The general shape of the steel pellets' downward velocity curve when compared to that of the lead pellets on chart number 5, shows why the forces of air resistance simply cannot be ignored, if a realistic appraisal of a pellets' potential downrange performance is going to be established.

This reduced velocity has a much lower striking energy potential, which makes a much larger difference to the hitting power of the steel pellets as is shown in chart number 6.
There is simply no substitute for increased pellet density, if higher retained downrange velocity is required.

Chart 6

The pellet striking energy levels of these same pellets tell a different story.
The difference in the downward striking energy curves on chart 6 of both pellet materials is similar, but the divergence of the lower density lead (4%) and the slightly smaller steel (so-called steel '9' 2.25mm) pellets from the lead (2%) and steel 7.5 (2.3mm) lines is more pronounced.
Both their slightly lower density and slightly smaller size has respectively reduced their hitting power to a greater extent.



	0yd	10yd	20yd	30yd	40yd
Lead 9(2%)2.03mm	2.92	1.73	1.14	0.79	0.57
Lead 9(4%)2.03mm	2.85	1.67	1.09	0.75	0.54
Steel 7.5 2.3mm	2.85	1.48	0.89	0.57	0.38
Steel '9' 2.25mm	2.68	1.37	0.82	0.52	0.34

Striking energy is shown in foot-pounds with the preferred minimum levels for consistent Clay pigeon breaks with a multiple pellet strike of: ‘Face on’ 0.5ft/lbs, ‘Edge on’ 0.75ft/lbs

Same weight pellet losses

Referring to the consistent multiple strike ‘edge on’ clay pigeon purple line on chart 6, the lead 9 (4%) 2.03mm pellet has 0.75ft/lbs of striking energy at 30yards, the steel 7.5 pellet (2.3mm but of equal weight) has this same energy level at 23.6yards; 6.4 yards less range.

The difference between the two same weight pellets is more pronounced at the 0.5ft/lbs line for 'face on' clay pigeons at the base of the chart. The steel UK7.5 (2.3mm) pellet reaches this at 33yards, but the lead 9 (4%) 2.03mm pellet, now has a 9yard advantage at 42yards.

Budget pellets

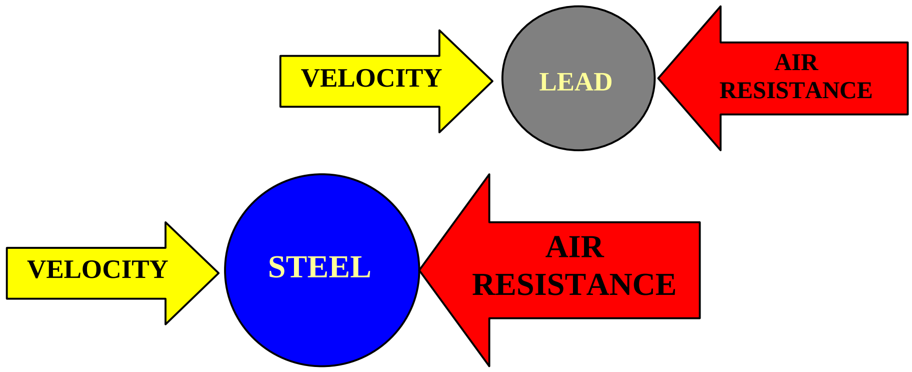
The difference between the slightly lighter steel '9' (2.25mm) pellet and the slightly heavier budget lead 9(2%) 2.03mm pellet is more pronounced, with the purple line being reached at 21.5yards and 31.5yards respectively. With the lead 9 (2%) having a full 10yards greater ranging power for 'edge on' clay pigeons.

Both pellet types reach the chart 0.5ft/lb baseline at 30.5 and 44yards respectively, a 13.5yard range advantage.

It is quite clear that using steel pellets of the same weight and number as lead, cannot ever overcome the limitations that their increased size has placed upon them by the laws of Physics. This is demonstrated in figure number 4.

Figure 4: Same weight pellets with identical velocity

Both pellets leave the muzzle with identical velocity and striking energy, but the effects of the increased forces of air resistance on the larger 'same weight' steel pellets' flight is both immediate and considerable.



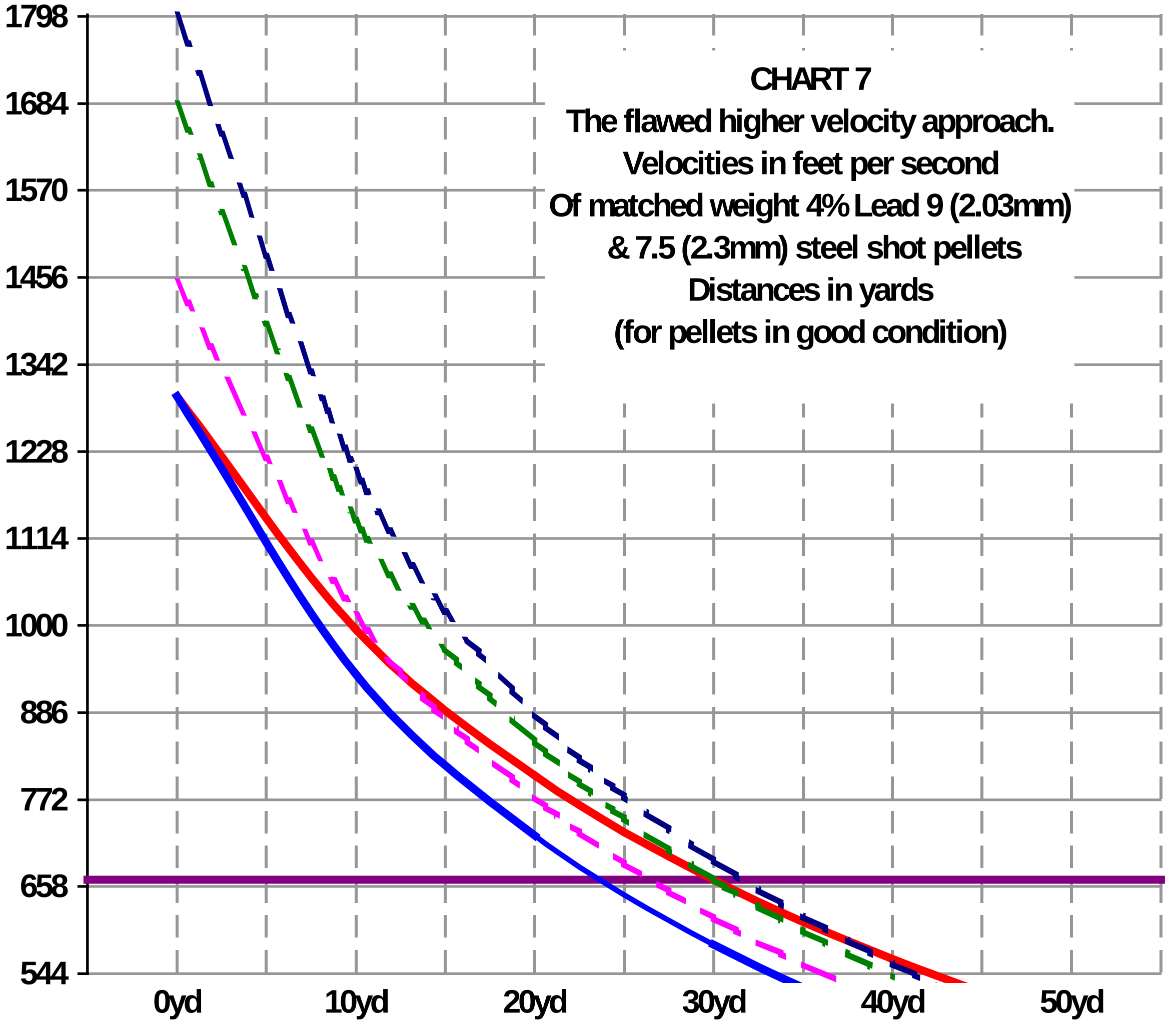
Although it weighs the same as the smaller lead pellet and has an identical number of pellets in any given loading, the larger steel pellet immediately attracts a greater degree of resistance from the air to its flight. This is because it has to cut a larger path through it, which creates more 'drag'.

This extra effort uses up greater amounts of its energy and thus slows it down more quickly, considerably reducing its' ranging and hitting power as a result.

Same weight pellets: The proposed higher velocity solution

The main response to this loss of downrange velocity with steel pellets is to have more of it in the first place. Unfortunately this vastly increases the braking effects of the air resistance upon the steel pellet as soon as it exits the muzzle and quite simply fails to deliver its stated objective downrange.

There are maximum strict velocity and momentum limits imposed by the International proof authority (C.I.P.), which effectively limit any such proposed hikes in speed of the same weight steel pellets. These limits are rarely approached by commercially loaded cartridges, as inadvertently exceeding them, might mean recalling the entire batch.



	0yd	10yd	20yd	30yd	40yd	50yd
Lead UK9 1300	1300	995	803	667	563	479
Steel UK 7.5 ill advised & implausible velocity	1800	1203	884	692	557	454
Steel UK 7.5 ill advised & impractical velocity	1684	1138	848	667	539	
Steel UK7.5 CIP Maximum Velocity	1450	1014	775	617	501	
Steel UK7.5 1300	1300	936	725	582	474	

Because both pellet types in fact weigh the same and they are the only types included, chart number 7 has the bottom line (the baseline) set at the velocity needed for the 0.5ft/lb minimum 'face on' clay pigeon multiple pellet striking energy level (544 feet per second).

This means that all of the various lines from the different velocities with the steel 7.5 pellets and the red line of the lead 9's, end at whatever distance in yards that they may be from their starting point, when their velocities have dropped to this minimum level of 544 feet per second.

The horizontal purple line represents the higher minimum velocity of 667fps (and therefore the higher striking energy level for a multiple strike of 0.75 foot pounds) required for the 'edge on' type of clay pigeon. Where the various lines intersect this purple line is the maximum 'edge on' clay pigeon range for consistently reliable breaks with a multiple pellet strike.

CIP Maximum allowable velocity

This shows that even when launched at the highest possible allowable C.I.P. velocity, the large increase in air resistance quickly drops the steel 7.5 pellets back down to match the initially much slower lead 9's at only 13yards range.

The net gain in range with this extra 150 feet per second over that of the normally available steel loadings is, 2yards for 'edge on' targets and 3yards when 'face on'; but the recoil generated will be a third heavier.

More velocity?

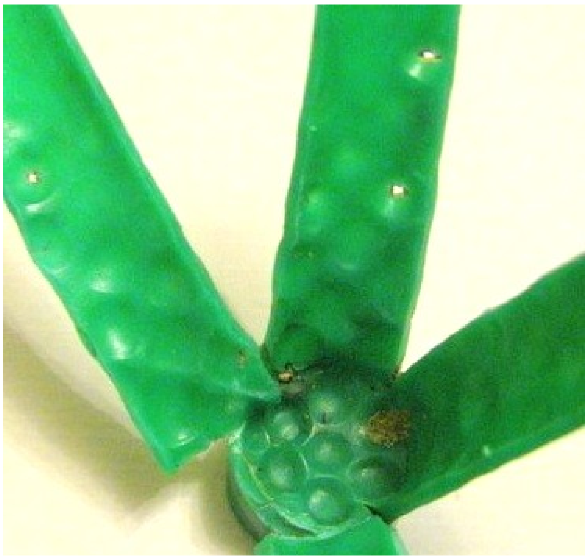
Although not within the C.I.P. rules for commercial production, it might still be suggested that a further increase in velocity with the steel 7.5's will balance out the performance disparity, with the normal velocity lead 9 pellets. It might seem logical, but would in fact be implausible with the currently available components. An even higher velocity than that allowed would generate a necessarily more rapid acceleration within the gun barrel to achieve it.

This would have to increase the side thrust of the pellets into the plastic wad against the chamber and barrel walls, which would mean that a thicker plastic wad section would be required to prevent any bore contact from the pellets. The space available inside the wad would in turn be considerably reduced, so a longer thicker walled component would be needed.

Figure 1 shows the effects of side thrust and the down force of rapid acceleration on the softer lead pellets. Much higher velocities have a similar effect to the heavier load as shown in the diagram and have much higher forces acting upon the pellets.

With the very much harder steel pellets, apart from some temporary elastic distortions, these forces tend to be transmitted much more violently against the chamber and barrel walls and are only prevented from doing so by the plastic wad cup walls.

If these forces are massively increased in their intensity, by the enormous acceleration needed to reach extremely high velocities, then the plastic wad cups must be strong and thick enough to prevent any compressive pellet contact being forced through them into the steel barrel walls.



Very high velocity USA Magnum steel loadings are not infallible.
Three steel pellets can be seen to have penetrated the special thick wad cup and impacted with the barrel wall.
The very high pressures needed to generate sufficient acceleration of the steel pellets to 1600 feet per second (in this particular case) have proved too much.
As the steel pellets get larger this problem becomes more acute.
NB these USA magnum loads are <u>not</u> permitted under the C.I.P. proof rules.

How much more velocity would be needed if it was allowed?

Extraordinary leaps in velocity are going to be required, which will inevitably be accompanied by unavoidably savage increases in both recoil and noise.

To match the 30yard performance (and velocity) of the lead 9's the steel 7.5's (that weigh the same) will have to be launched at 1684feet per second. Although a full 384 feet per second faster and now level with the lead 9's at 30yards, the steel 7.5's still fall 2.5 yards short (39.5yards) of the lead 9's (chart baseline) performance of 0.5ft/lbs at 42yards.

The recoil generated by this velocity would also rise by a huge 95%, very nearly double. This load would contravene the CIP steel shot rules.

Even by going to the extreme outer limits of relatively recent shotgun shell performance development in the USA, for 3.5inch chambered magnums with their special high pressure proof limits, the problem of steel's lack of density and therefore downrange performance (with same weight pellets) stubbornly refuses to go away.
At a staggering 1800 feet per second state of the art USA magnum velocity, the steel 7.5's are only fractionally ahead of the lead 9's at 30yards, but they still fall short (at 41yards) of the lead 9's (42yards) by one yard.

The recoil of such a load, if it were even possible to produce one that fell within the CIP proof pressure limits, would be a brutal 135% heavier than the normal lead UK9 loading whose downrange performance it was trying to emulate. This would feel considerably worse than firing both barrels at the same time.

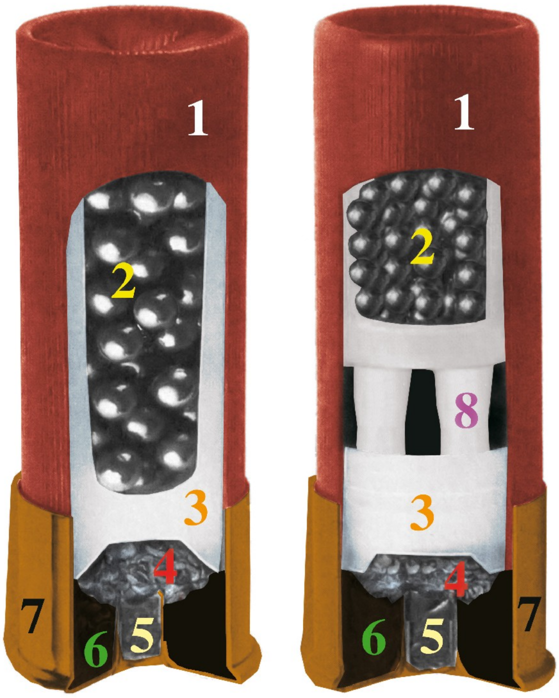
Conclusion

Budget steel shot 24gm cartridges are only slightly cheaper than the lead 21gm shells, which are surprisingly effective.

With enormous velocity increases (that are implausible, impractical, ill advised and have much higher pressures near the muzzle end of the barrel than current guns were designed for), matching up steel and lead shot pellet weights, (and numbers) can never work, because the greatly increased 'drag' of air resistance always works against the larger steel pellets.

Although still unable to match the normal lead loads, these radical steel loads would prove to be much more expensive than those currently available.
Special powders and wadding components would be needed, perhaps with longer three inch cases and a special high pressure steel shot proof, but huge numbers of currently used clay pigeon guns would not be able to accommodate them.

The tremendous muzzle blast and very heavy recoil of such radical cartridges would be out of the question for clay pigeon shooting.



STEEL SHOT LEAD SHOT

1 Case, 2 Shot, 3 Plastic Wad , 4 Powder, 5 Primer, 6 Shock absorbing and Gas sealing base wad (this is considerably lower in this particular steel load), 7 Metal case head, 8 Cushioning section of The lead Shot plastic wad (not present in the steel load).

Summary

In part one we saw that steel shot's lack of density, (weight) when compared with Lead shot means that it is completely unable to compete with the same shot sizes.

Having many more same sized steel pellets in the same weight of load is of no effective benefit to the shooter for shooting identical courses of targets.

This is because the steel pellets are much lighter and so get progressively slower as they travel downrange, as a result their target breaking power is but a small percentage to that of lead.

Attempting to counter this by pushing these same sized steel pellets right up to the recommended maximum (C.I.P. proof authority) velocity is impractical, as there is no worthwhile improvement in ranging power.

Steel shot pellets have caused barrel damage when they have been in contact with either the chamber, chamber cone, chokes or steel barrel wall: their material hardness makes this inevitable.

In part 2 we saw that in other countries including the USA, the dangers of steel pellet ricochets from a multitude of hard surfaces is recognised and controlled, as it severely limits the safe applications of steel shot for clay pigeon shooting.

Picture: 28grams of UK7 lead shot have 43% more pellets than 28grams of 3mm steel (FE5/UK4)

In part 3 using excessive amounts of choke constriction with steel shot was seen to be counterproductive, as it has the effect of delivering inconsistencies, with erratic pattern spreads, much longer shot strings, variable points of impact of the pattern placement and widely varying pellet velocities.

Within the relatively short ranges where steel can break targets reliably, open chokes are quite sufficient.

There is also the possibility that with repeated use, the excessive side thrust pressures through overly tight chokes from the non-yielding steel shot pellets, may damage either the muzzle or choke tube of some guns.

In part 4 we have seen that steel and lead shot budget cartridges are not that dissimilar in price and that the same sized steel and lead pellets do not work, even at totally impractical velocity and recoil levels.

Beyond this series

To keep within C.I.P. velocity limits and retain sensible recoil levels for normal competition shooting, there is the ‘Catch 22’ situation of sufficient ranging power and the much larger steel pellets necessary to achieve this.

Picture: even with maximum 32gram loads that take up all of the available space in the 2,3/4inch case, the steel 3mm FE5 / UK 4’s (left) and the steel 3.25mm FE4 / UK 3’s (right) are struggling with greatly reduced pellet numbers.

But this is a solution with diminishing returns, as the much larger steel pellets (much larger than the largest size currently allowed) have the downrange striking energy needed, they do of necessity, throw considerably sparser patterns, dictated by their greatly reduced numbers. For their extreme range targets, FITASC shells would need even larger steel pellets but that would exacerbate the patterning problem. There are many other remaining steel shot issues as well as this one, but a full explanation of them all will have to wait until another time.