Cast Bullet Alloys & Alloy Maintenance

By: Rick Kelter

Just about every alloy containing lead has been used to cast bullets at one time or another with varying degrees of success. Many bullet casters use an alloy simply because it's what they have available without giving much consideration to the type of shooting the bullets are intended for. If competition and the best possible accuracy and velocity, or hunting bullets with a known amount of or lack of expansion are the goals, repeatability from batch to batch of the alloy is mandatory and a reliable, consistent source of alloy is needed, more on this further on. Informal plinking or practice ammo and very short ranges can tolerate much more variation in bullet alloy. Accuracy is a relative thing, what is outstanding accuracy for one person and his type/style of shooting, his type of firearm and his skill level would send another bullet caster running back to the drawing board to find out what went terribly wrong. Your type of shooting, your firearms and most important, the level of accuracy that you are willing to accept should guide you in selecting bullet alloys.

A very common misconception is that cast bullets lead the bore because the alloy is too soft, in reality this is very rarely the case. Poor bullet fit in the firearm is responsible for more leading problems than is the alloy BHN (Brinell hardness number) being too low. Poor or improper chamber and bore dimensions with incorrectly sized bullets and poor or inadequate lubrication rank next in causing leading ahead of bullet BHN. This is not to say that there aren't soft bullets, its just not the first thing you should think of. I did extensive BHN testing in my 9" Freedom Arms 357 Magnum revolver using maximum long range accuracy loads. Testing was with air cooled wheel weight alloy at 11 BHN and with heat treated alloy of varying BHN up to 30. Many hundreds of rounds were fired in 5 shot groups at 150 meters scoped from the bench and not a single load caused any leading, not 11 BHN, not 30 BHN. These were top end 357 loads with a 190 gr. bullet at 1550 fps proving (in my mind at least) that bullet fit in a properly dimensioned firearm is far more important than alloy BHN. The only leading that I have ever been able to cause in this revolver is with bullets that did not properly fit the cylinder throats. As an example, the SAECO 35 caliber bullet # 399, 180 gr. TCGC (truncated cone, gas check) is a two diameter bullet with the front driving band .005" smaller than bullet diameter and there is no way to size this bullet to fit was a happy man. The popular term "Hard Cast" clouds the issue for new casters and purchasers of commercial cast bullets and causes trouble with both leading and accuracy when the more important issue is bullet fit. Assuming a proper bullet BHN (not too hard) for the loads pressure and firearm the more important issue with bullet BHN is consistency. Shooting groups with bullets of varying BHN opens up long range groups and increases the velocity extreme spread, consistent alloy is an important part of maintaining consistent BHN. For the hunter using cast bullets his alloy consistency is every bit as important as it is for the competitive shooter. Consistency of his alloy will determine the amount of bullet expansion (or lack of) from batch to batch and from hunt to hunt. If the hunters alloy varies from his tested ammo his pre-determined level of accuracy, expansion and bullet upset may not be so predictable.

The Four Important Metals in Cast Bullet Alloys

Lead (Pb) melts at 621.3^o F and has a BHN of 5. Lead alloys with some metals very well, not so easily with other metals. Lead is a very heavy, ductile or if you prefer malleable metal. Its weight is what carries the bullets momentum to the target and being malleable is what allows it to conform to the bores dimensions (obturation) and seal off the rising gas pressure. Alloying lead beyond what is needed for the lowest practical strengthening can have consequences in reducing the sectional density of the bullets and this could have consequences for match loads on long range accuracy, velocity and momentum.

Unlike most types of steel alloy's that become more brittle when heat treated, lead alloy can be heat treated and made harder without adding any brittleness. Unlike most types of steel alloy's (or your brass cartridge cases) that become harder and brittle when worked, lead when worked becomes softer and more malleable. Heat treated lead, unlike steel, does NOT surface harden but achieves the same BHN all the way through.

It is a common misconception that because they are less dense than lead, antimony and tin may undergo gravity separation from the melt. Nothing could be further from the truth. In the absence of oxygen or oxidizing materials, melted lead alloys will remain stable and mixed virtually forever. And from Lyman, *Perhaps the single most significant error in all the bullet casting literature is the misconception that lead-tin-antimony alloy melts gravity segregate.*

Lead conducts heat slowly and contrary to the belief of some, lead does not melt from the base of plain base bullets when fired causing leading. If it could why don't paper and plastic wads burn in shotgun shells? The millisecond the bullet is subjected to this heat simply could not melt lead. Pressure forcing the bullet against the sides of the bore could and far more likely than this is a lack of obturation (bullet too hard) allowing gas leakage down the sides of the bullet. This has the same effect as an acetylene torch cutting steel and leading would begin on the trailing edge of the rifling.

*Molten lead alloy exposed to air soon oxidizes (*this is NOT gravity separation*). This oxidation affects all the constituents, including the lead. (The chemistry of tin and antimony dictates that they oxidize at a higher rate, which accounts for their gradual depletion from the melt.) Thus, the scum which forms on the surface of the melt is a mixture of metal oxides, not tin or tin oxide only. Fluxing returns much of the oxidized metal to the melt.* Oxidation occurs only at the surface of the melt (and in the flow stream from bottom pour pots), however, within the pot of melted alloy there are thermal currents, the coolest alloy at the surface sinks and hotter alloy (mostly from near the sides of the pot where the heating element is) rises to the surface. The entire volume of alloy in the pot is subject to oxidation. (Tin helps *reduce, not eliminate* oxidation up to a max of 750^{o}.) The bottom line, oxidation occurs wherever, whenever the molten alloy is in contact with air and thus the need for fluxing (fluxing returns metal oxides to the alloy).

Antimony (Sb) melts at 1167^{o} F. It is the current metal used to strengthen/harden lead alloys for bullet casters and for numerous applications in the metals industry. It is an extremely brittle metal but has unique characteristics in a lead alloy in addition to its basic hardening, such as the ability to heat treat a lead alloy bringing the final hardness up far more than what the percentage of antimony would suggest. Alloys such as monotype (19% Sb) and stereotype (23% Sb) are so brittle that bullets cast of them can actually break in two by simply chambering a round or dropping it on the floor. Antimony is a valuable part of the bullet casters alloy but too much of a good thing is clearly not a good thing. The type metals, linotype, monotype and stereotype, if you can still find them, are valuable to the bullet caster for their antimony and tin content when blending (alloying) with other lead alloys.

Antimony is a silver white metal, very hard and brittle. It has no characteristic crystallographic surfaces when sheared. Melting temperature is 1167°F and even when melted at or above that temperature it is not easy to get a homogeneous alloy with lead. As soon as the pour is started the rapid cooling causes an increasing amount of antimony to solidify while pouring. The addition of tin does help by providing some protection against oxidation of the melt.

Decreasing the antimony percentage much below 4% has a dramatic effect on the time curve of heat treated bullets. In my heat treating experiments alloy with less than the typical 3-4% antimony in wheel weight alloy didn’t result in softer heat treated bullets but rather, bullets that took considerably longer to age harden and reach their final hardness, up to two weeks longer. I found this test fascinating, reduced antimony didn't reduce the final *heat treated* BHN but rather increased the age hardening time about 8 fold.

Lead/antimony alloy dross's considerably. As your melt reaches liquidus temperature that silvery, lumpy, oatmeal looking stuff floating on top is antimony. Skimming it off seriously depletes the alloy; it needs to be fluxed back into the melt.

Key factors of antimony in lead alloys: Adds strength as well as hardness. Like tin it helps pick up fine details of the mould and allows the alloy to flow easier. It lowers the solidification temperature and raises the molten temperature. It is extremely brittle and terminal ballistics should be considered when choosing an alloy with a high percentage of antimony. Permits hardening by quenching or heat treating.

Antimony can be purchased online from the "Antimony Man" but with its high melting point it is a somewhat arduous task trying to alloy it with lead. The Antimony Man supplies instructions on alloying antimony with the purchase that include the warning that the instructions must be followed precisely to be successful. In addition, antimony is extremely toxic, when handling it in a powdered form proper breathing protection and proper clean-up techniques of surrounding surfaces should be used.

Tin (Sn) melts at 429^o and alloys very easily with lead. Tin was used for many years as *the* hardening agent in lead. In the years of large caliber, big bore black powder cartridges the minimal hardening effects of tin was sufficient. With the advent of smokeless powders and much higher pressures and velocities and far sharper pressure/time curves of the faster smokeless powders tin's limited hardening/strengthening effect on lead left alloys too soft for many cartridges.

Lead/tin alloy's age soften quickly and the higher the percentage of tin the faster the age softening. If your lead/antimony/tin bullets are to be quenched or heat treated (lead/tin alloy does not respond to heat treatment) the percentage of tin will affect the final amount of hardening that can be achieved, the higher the percentage of tin the lower the final BHN in addition to faster age softening. Lead/tin alloy should age soften at a fairly steady rate for 25 or 30 days and then soften very slowly after that. Be that as it is, tin is still a very valuable addition to the bullet casters alloy. The true value of tin for today's bullet caster is that it helps reduce dross during casting which enables it to reduce the surface tension of the melt. It does this by inhibiting the oxidation of the metal entering the mould and enabling a more complete fill-out of the moulds intricate details. NOTE: It is not only the surface of the melt in the pot subject to oxidation, the stream of alloy from a bottom pour pot or casting ladle is also in contact with oxygen and this is where tin has it's largest benefit in reducing oxidation and aiding better mold fill-out, from the spigot to inside the mold. Tin does add some hardening/strengthening to lead alloys but at the percentages in most bullet alloys it is minimal. *Maximum hardness of lead/tin alloys is 17 BHN at 63% tin and 37% lead* (commonly known as 60/40 solder). Tin lowers the melting point of lead alloys, eutectic 60/40 solder melts at 361^o F. Loss of tin from the alloy from oxidation is low as long as the melt is not overheated. *Tin provides dross protection up to about 750^o and also improves castability.* Casting temperatures with alloys containing tin should be held to about 700^o so that tin's ability to reduce dross won't be lost.

Arsenic (As) melting point, 1,503^o F. Arsenic is a catalyst to heat treating Pb/Sb alloys and only a trace is required (¼ to ½ of 1%), adding more than this will do nothing to further harden the alloy. Arsenic in itself does little to harden the alloy; its value is as a catalyst in heat treating (or quenching from the mould) lead/*antimony* alloys. Arsenic is of coarse very toxic but at the percentage in and temperature of bullet alloys the risk is nearly non-existent. However, the bullet caster should never attempt to alloy elemental arsenic into his alloy (if he could even get it). *At the temperatures required arsenic sublimes, that is, it transforms directly from the solid to a gaseous state, emitting highly toxic smoke. Leave this to the experts*. In addition to arsenic subliming other forms of extremely toxic gases, such arsine are formed and this should be left to the professionals. Wheel weights, chilled shot and magnum shot are excellent sources of arsenical alloys for the bullet caster to enrich his alloy for *about 1 or 2 BHN*. Arsenic's true value is in heat treating lead/*antimony* alloys. With a trace of arsenic a much higher BHN can be achieved while using a much smaller percentage of very brittle antimony.

Salvaged lead from sail boat ballasts could be and probably is almost anything. It would be made up of anything each boat manufacturer could scrounge up and pour into a mould to fit his hull. If you get a supply of this try casting a few bullets with it (before adding it to alloy of known quality) to check its castability and a few days later check its BHN so that you have a better idea of what you have.

Salvaged range lead can be quite the mix unless you're familiar with the range and know that a specific type of shooting is mostly done, *.22 lead is mostly lead, virtually no antimony, and usually about 1-2% tin. Jacketed bullet alloy composition ranges anywhere from pure lead to 5% Sb. As a very general statement, many* *handgun jacketed bullets have pure lead cores (almost all Noslers, almost all FMJs, and most std. velocity jacketed handgun bullets). Some have hardened cores (e.g. the Sierra 300 grain .44 Mag bullets is 5% Sb). If the range has centerfire rifle bullets, then they are commonly 3% or 5% Sb. So the bottom line is that jacketed bullets can contribute almost any hardness to bullet metal.* I have read reports of shotgun slugs being from near pure lead to approximately 2-3% antimony. As with the sail boat ballast, check to see how well it casts and check its BHN, checking the weight against bullets from the same mould cast with a known alloy composition could help identify the alloy, or at least narrow it down.

Before blending any salvaged alloy with an alloy of known quality cast a few bullets with it to assure that you don't have zinc or other contaminates in the new alloy.

Salvaged battery lead should be avoided at all costs. Since the advent of the maintenance free battery the lead content has been reduced and elements such as strontium, calcium and others have been added. Most of these elements cast very poorly, ruin a pot of good alloy they are blended with ***and are extremely toxic*.** The quantity and quality of lead from batteries is not worth the risk or the effort.

From "Linstrum" on the Castboolits forum - *Maintenance free/low maintenance batteries use calcium metal-doped lead to catalyze the hydrogen gas. The lead alloy used in batteries also contains a bit of antimony and arsenic to help harden and strengthen the lead. When hydrogen comes in contact with arsenic and antimony, the hydrogen reacts to form ammonia analogues called arsine and stibine, AsH_3 and SbH_3. In World War One the Germans experimented with these as war gases. As such they were highly effective since they are deadly in amounts too small to easily detect.*

Do yourself and everyone else in the vicinity a favor and DO NOT use batteries. Severe lung damage and even death could result. Sell the batteries to a recycler and let the professionals deal with the risks.

Linotype: is the most common and popular of the type metals used for bullet casting. At 84% lead, 12% antimony and 4% tin, lino is a eutectic alloy meaning that it melts and freezes at one temperature (464^{o}) with no slushy stage, just as single metals such as tin. With its percentages of antimony and tin the fluidity of lino is exceptional and casts perfectly filled out bullets.

An advantage/disadvantage of lino is its 12% antimony. The advantage is in taking advantage of its 12% antimony and using it to alloy with other lead alloys. The disadvantage is that 12% antimony is a lot and produces very brittle bullets. Bullets cast of straight lino are brittle enough that they can be a poor choice for hunting bullets if any nose deformation is desired or for use on heavy steel targets where it can and does shatter. Monotype (19% Sb) bullets with only 7% more antimony are so brittle dropping one on the floor or even simply chambering the round can actually break it in two. The printing industry hasn't used type metals in years and it's getting fairly difficult to find. If you're going to cast of straight linotype they are quite hard at 22 BHN and should be used with a load that generates a minimum of 31,000 PSI to assure obturation.

Lino with its eutectic 464^o melting point can and should be cast at a lower temperature than many alloys. The common practice of casting at 700^o to 750^o or hotter is at least 236^o over its liquidus temperature. Dross formation and metal loss from oxidation can be reduced by casting a little cooler, about 550^o-600^o. An additional benefit of the reduced temperature is that the mould doesn't get as hot and you won't have to wait as long for the alloy in the mould to freeze, you can actually cast at a faster rate. When casting lino at 550^o-600^o be cautious of adding new alloy to the pot too quickly and lowering the pot temperature below the liquidus and causing dross to form or dropping the pot temp below liquidus temp..

Wheel Weight Alloy: *Metallurgically or otherwise, there is no justifiable disadvantage to using wheel weights for cast bullets. The wheel weight composition of 9% antimony in older editions of the Lyman Reloading Handbook is <u>very much out of date</u>. Recently obtained wheel weights average about 3% antimony max.* There's not much doubt this is where the conventional wisdom comes from that wheel weight alloy isn't a good bullet alloy because the composition keeps changing. It *was* changing 25-30 years ago, it has been reasonably stable since then with minor changes from manufacturer to manufacturer as the price of raw materials fluctuates. I have used, heat treated and tested wheel weight alloy almost exclusively for well over 15 years and haven't found a difference significant enough to effect the alloy ballistically. There can't be any doubt that there are minor differences from manufacturer to manufacturer and year to year as the cost of raw materials fluctuates, but the simple truth is that there hasn't been a difference significant enough to affect groups, velocity or final heat treated BHN during this 15 year period. My notes indicate that the wheel weight alloy I have recently heat treated achieved the same final BHN as bullets heat treated 15 years ago. Pre-heat treated, as cast wheel weight alloy has fluctuated from 10 to 12 BHN during this time and my current batch (about 500 pounds) is 11 BHN. Pre 1970's wheel weights averaged 9% antimony and during the 70’s this average was reduced, since the early 1980’s there appears to be little fluctuation in the percentage of antimony in wheel weight alloy and currently seems to be about 3%, maybe, maybe ... 4%. Remember in the first paragraph I said consistency in alloy from batch to batch is important? Wheel weight alloy has done this for me for the last 15 years.

It's an alloy that is readily available all across the country and anywhere from free to fairly cheap. At 10-11 BHN air cooled with a couple percent of tin added it is a good alloy for most non-magnum handgun loads and many light to medium rifle loads. As an example, my 308 rifle shoots 11 BHN air cooled wheel weight with 185 grain bullets at 1900 fps into surprising groups at 100 and 150 yards with no leading. Wheel weight alloy is an ideal bullet alloy for heat treating because of its percentage of antimony and a trace of arsenic. This alloy can be heat treated to 30+ BHN. Most loads do not generate nearly enough pressure to cause obturation at 30 BHN and yes, obturation is a good thing. Very top end 454 Casull loads at 65,000 PSI should work well with 30 BHN bullets.

When processing your wheel weights into ingots you should always separate the clip-on weight from the stick-on weights (the ones with foam tape on the back). Stick-on weights are nearly pure lead and by including them in your alloy you are softening the entire batch by diluting the antimony content. In addition, if your goal is to achieve consistency of your alloy, the quantity and the size of stick-on weights in each batch will vary considerably making it impossible to duplicate the alloy the next time. Plus, it seems such a waste of a good source of soft alloy.

More and more wheel weight manufacturers are using zinc, steel, alloy and even plastic weights in place of lead. Zinc weights can be difficult to detect when processing into ingots (some are painted to match tire rim color) and zinc in your alloy will cause all sorts of casting problems. Wheel weight alloy melting point is under 600^{o}F and zinc melts at 787.15^{o}F. When processing your weights into ingots keep the pot temperature at or only a little above 650^{o} and no hotter, the zinc weights will float before they melt. If you see anything floating, remove it immediately.

An Additional Consideration for Alloys: In addition to bullet base obturation additional considerations concerning alloy strength and hardness in higher pressure/velocity rifle loads are velocity, free-bore jump to the rifling and the rifling rate of twist. The alloy must have the strength to make the free-bore jump and take the rifling without stripping. A faster twist rate or longer free-bore jump could possibly require a bit harder alloy; cast bullets could suffer more from a longer free-bore jump and a sharper twist rate than their jacketed counter parts. Additionally, unsupported bullet noses (bore riders) can slump to one side under the stress of acceleration; bullet design can play a role here as well as alloy strength. It can be a balancing act that requires testing to determine the *minimum* hardness (strength) of the alloy for these conditions and yet not be too hard for that all important obturation.

Common Bullet Alloys, Composition and Hardness

Alloy	Tin%	Antimony%	Lead%	BHN	Arsenic (Trace)
Foundry Type	15	23	62	?	No
Monotype	9	19	72	28	No
Stereotype	6	14	80	23	No
Linotype	4	12	84	22	No
Lyman # 2	5	5	90	15	No
Electrotype	3	2.5	94.5	12	No
1 to 10 tin/lead	9	---	91	11.5	No
1 to 20 tin/lead	5	---	95	10	No
1 to 30 tin/lead	3	---	97	8	No
1 to 40 tin/lead	2.5	---	97.5	6-7	No
Hard Ball	2	6	92	16	No
Clip-on wheel weight	.5	2	97.5	11 12	Yes
Stick-on wheel weight	*	**	99.5	6	No
# 8 Magnum	---	2-3%	97-98	***	Yes
Plumbers Lead	---	---	****100		No
Lead	---	---	100	5	No

*Not known, presumably .5 to .75% tin. Stick-on weights are nearly pure lead with a BHN of 6.

**Not known, presumably there is no Sb in stick-on weights.

***# 8 Chilled Shot + 3% tin and cast into bullets tested 8 BHN.

****Plumbers lead should be nearly pure lead as is cable sheathing, lead salvaged from X-ray rooms and roofing sheets. It may not be pure enough for the purist front stuffers but it's pretty soft and valuable for alloying with the type metals or Roto Metals Super hard.

Alloy Maintenance: It's not quite as simple as turning on the electric pot and pouring. A basic knowledge of caring for your alloy is required and there are a few tips that once understood makes this fairly simple. If these rules are violated the percentages of metals and quality of the alloy in your pot may not be what you thought it is.

One of the most critical yet least understood casting factors is temperature. When a bullet caster refers to the melting temperature of the alloy, what he means is the solidus or the temperature at which the alloy begins to melt. More important is the liquidus temperature of the alloy, the point at which the alloy is completely molten. An alloy may appear to be completely melted in the pot when in actuality it is not, since crystal formations of some of the important constituents of the alloy, such as tin and lead or lead and antimony, still exist. What this means for the bullet caster is do not flux or add alloy (sprues, rejects or new ingots) to the pot until the alloy has reached the liquidus temperature. After adding alloy to the pot wait for the liquidus temperature to be reached before fluxing. Every time metal is added to the pot the alloy should be well fluxed. Once the liquidus temperature is reached stir the melt before fluxing to assure even heat throughout the melt. Add alloy to the pot slowly to aid in keeping the melt as close to the liquidus temperature as possible.

Dross forms in a pot of molten metal by oxidation of the metal from exposure to heat, air, impurities, and dirt, and from running the alloy <u>below</u> its liquidus. As the metals melt, dross's (oxides of the metals) appear on the surface of the molten metal. They must be returned to the melt by fluxing, or else their removal as dross seriously depletes some of the important constituents of the alloy. Additionally, running the alloy too hot causes metal loss through oxidation and more frequent fluxing to return dross to the melt.

Do not allow the level of alloy in the pot to get below about half full so that proper temperature can be maintained, the temperature of many electric pots will rise as the level of alloy in the pot falls. Be cautious of the temperature falling below the liquidus point. Do not run the pot temperature any higher above its liquidus temperature than necessary, about 50^o - 75^o F.

Solidus and liquidus temperature. The solidus temperature is easy to determine (the alloy begins to melt) but what is the liquidus temperature, the point where there are no crystalline structures and all of the constituents of the alloy are completely melted? To be honest I don't know, it would depend on the metals in your alloy and the percentages of them. To play it safe my practice has always been simply to wait until casting temperature is reached before fluxing or adding alloy. I cast wheel weight alloy at 700^o and this is the temperature that I add alloy (even rejects or sprues) *and* flux. Once I have fluxed I do not add anything to the pot through the entire casting session, not even rejects or sprues. This is a simplified method of how the metals industry maintains quality when blending alloys. In the industry, metals are added to an alloy at a very specific temperature that is based on the metal being added and the metals already in the alloy. This would be quite an excessive degree to take bullet casting, as long as metal is added and fluxing is done *after* liquidus temperature (casting temperature) is reached we can maintain the integrity of our alloy.

Key Points: All of this might sound complicated but in reality as bullet casters we don't need to be metallurgists but we do need an understanding of the basics. In the above paragraphs you have learned what the basic metals and bullet casting alloys are, some of their important characteristics and how to care for them. Here is a review.

1> When accuracy, velocity or expansion are the prime concerns, consistency of the alloy from casting session to casting session and batch to batch is important. Consistency of the alloy BHN is important to both grouping and velocity extreme spread.

2> Too hard can be worse than too soft. If your cast bullets are leading don't automatically assume the alloy is too soft, the problem could very well be poor bullet fit or too hard of an alloy. Lead absorbs heat slowly and it is extremely doubtful that bullet bases melt. Far more likely causes of leading are bullet fit, lack of obturation, firearm dimensions or lubrication. Don't blame the alloy for something that it didn't cause.

3> Antimony hardens / strengthens lead. It helps the alloy flow and fill out the mould with better, sharper detail. It is extremely brittle and if the bullet is for other than paper punching the antimony should be held to about 5% of the alloy. Antimony is what enables the heat treating of lead alloys.

4> Tin adds both *minor* strength and *minor* hardening to bullet alloys. It reduces the surface tension of the melt allowing the metal to flow and better fill-out the fine details of the mould. Tin provides dross protection up to about 750^{o}. Tin reduces the melting point of lead alloys plus the higher the percentage the more it limits the amount of heat treating that's possible. Higher percentages of tin cause faster age softening.

5> Arsenic is like a "*catalyst*" in lead/*antimony* alloys enabling hardening (strengthening) by heat treatment far above what the percentage of antimony would suggest. Only a trace is needed and adding more will *not* further harden the alloy. Arsenic itself adds very little to the hardness of lead alloys. Wheel weights, chilled shot and magnum shot are excellent sources of arsenical lead alloys for the bullet caster to enrich his *antimony* alloy for quenching or heat treating.

6> The type metals are an excellent source of antimony and tin (but not of arsenic) for alloying with soft salvaged lead alloys and an unlimited variety of different alloys can be made.

7> Clip-on wheel weights and stick-on weights should be separated when processing wheel weight into ingots. Clip-on wheel weights are an excellent bullet casting alloy with its percentages of lead/antimony and arsenic. 2% tin can be added for better dross control and thus mould fill out. This alloy runs 10-11 BHN air cooled and can be heat treated to 30+ BHN. Proper fitting bullets of 11 BHN in a properly dimensioned firearm are adequate for all but magnum handgun loads, water quenching or heat treating wheel weight alloy will easily extend its use to magnum handgun loads and mid-range rifle loads. When processing wheel weights into ingots the melt temperature should not be much over 650^o and keep a watchful eye for zinc weights.

8> Stick-on wheel weights are an excellent source of very soft alloy (about 6 BHN). This alloy makes very effective HP bullets for light and medium pressure 45 ACP loads and expansion is dramatic. It is fairly close to a pure lead and can be used to alloy with the type metals.

Stick-on WW, 45 ACP 200 gr. HP @ 800-850 fps fired into water.

9> The alloy should not be fluxed or metal added until it reaches its liquidus (*casting temperature*.) After alloy is added wait for the temperature to return to its liquidus *before* fluxing. Don't skim off the metal oxides, flux them back in. Keep the alloy well fluxed. Don't run the pot temperature any higher above its liquidus than necessary (about 50^o F is fine) to keep oxidation to a minimum. A tip on reducing oxidation of the melt, using a flux that doesn't burn off (such as sawdust) and leaving it on top of the melt after fluxing and while bottom pour casting and will help keep air off the surface and reduce oxidation. Try and avoid air flow (an electric fan for example) across the top of the melt.

10> It should be obvious by now that a critical piece of casting equipment for maintaining consistent alloy from batch to batch, maintaining the integrity of the alloy and casting bullets of consistent, repeatable quality is a quality lead thermometer.

Alloy Recipes

(Formulas using magnum shot Computed @ 4% Antimony and 1½% arsenic

Formulas using stick-on WW computed as straight lead
Formulas using clip-on WW Computed @ 3% Antimony and .5% tin)

Linotype - 3 pounds Clip-on Wheel weights - 9 pounds Tin / Antimony / Lead 1.4% / 4% / 94.6% Add 1% tin.	Monotype - 2 pounds Clip-on Wheel weights - 4 pounds Lead - 3 pounds Tin / Antimony / Lead 2.2% / 5.25% / 91.9% Good Magnum alloy	Clip-on wheel weights - 20 pounds Stick-on wheel weights 15 pounds Lino 5 pounds Lead Shot - 4 ounces Tin - 9.6 ounces Tin / Antimony / Arsenic / Lead 3% / 4% / .25% / 92.75 % Quench/oven HT to 18 - 30+ BHN
Linotype - 5 pounds Clip-on Wheel weights - 5 pounds Tin / Antimony / Lead 2.25% / 7.5% / 90.25% Approximate Hardball BHN	Linotype - 2 pounds Clip-on Wheel weights - 5 pounds Tin / Antimony / Lead 1.5% / 6.3% / 92.2% Nearly Lyman # 2 BHN	Clip-on wheel weights - 20 pounds Tin - 6.4 Ounces @ 2% or 9.6 Ounce @ 3% Tin / Antimony / Arsenic / Lead 2 1/4% / 4% / 1/4% / 93 1/2% Oven heat treats to 30 - 34 BHN
Linotype - 4 pounds Clip-on Wheel weights - 6 pounds Tin / Antimony / Lead 1.9% / 6.6% / 91.5% Approximate Hardball BHN	Monotype - 3 pounds Clip-on Wheel weights - 4 pounds Lead - 3 pounds Tin / Antimony / Lead 3% / 7.2% / 89.8% Medium hard alloy. Magnum handgun & rifles to 2,000 fps	Clip-on Wheel Weights - 9 pounds 50/50 bar solder - 1 pound Tin / Antimony / Lead 5% / 3% / 92% Close to Lyman # 2 Alloy
Clip-on Wheel weights - 10 pounds Stick-on Wheel Weights - 4 pounds Tin / Antimony / Lead .35% / 2.2% / 97.65% Trace of Arsenic - About 7 BHN	Clip-on Wheel weights - 10 pounds Stick-on Wheel Weights - 4 pounds Virgin bar tin - 4 ounces Tin / Antimony / Lead 2.1% / 2.1% / 95.8% Trace of Arsenic - About 7-8 BHN	Clip-on Wheel weights - 9 pounds Linotype - 2 pounds Virgin bar tin - 7 ounces Tin / Antimony / Lead 4.9% / 4.45% / 90.65% Lyman # 2 Alloy duplicate

NOTE: Not all alloy recipes listed above were tested by the author. Super Hard, custom alloys or pure alloys can be ordered to your specifications from Roto Metals, Inc. w/free shipping on many orders. Formulas using additional tin used 99.9% pure bar tin unless noted.

From the print industry circa 1970.

LASC	Composition %			Degrees F.		Brinell Hardness
	Tin	Antimony	Lead	Solidus	Liquidus	
Electro	2	6	92	462.2	534.2	16.5
Linotype	2	11	87	462.0	480.0	18.0
	4	11	85	462.0	476.0	22.0
	4	12	84	462.0	463.0	22.0
	5	12	83	462.0	475.0	22.0
	6	12	82	462.0	477.0	22.0
*Stereotype	6	14	80	462.0	493.0	23.0
	6	16	78	462.0	501.0	25.0
Monotype	8	16	76	462.0	512.0	27.0
Foundry Type	10	20	70	462.0	553.0	30.0
	12	23	65	462.1	620.0	33.0

Chart source: The Australian Printers' Handbook, E.C. Bernett 1950, Type Metals, Engelhard Wallace Pty, Ltd, 1970.

Note five different grades of linotype in the chart. The most common and the recipe best known as "lino" is 4/12/84, Tin/antimony/lead.

Unified Numbering System - (UNS) designations for various pure lead grades and lead-base alloys. If you acquire ingots with any of these numbers, this what you have.

- Pure leads L50000 - L50099
- Lead - silver alloys L50100 - L50199
- Lead - arsenic alloys L50300 - L50399
- Lead - barium alloys L50500 - L50599
- Lead - calcium alloys L50700 - L50899
- Lead - cadmium alloys L50900 - L50999
- Lead - copper alloys L51100 - L51199
- Lead - indium alloys L51500 - L51599
- Lead - lithium alloys L51700 - L51799
- Lead - antimony alloys L52500 - L53799
- Lead - tin alloys L54000 - L55099
- Lead - strontium alloys L55200 - L55299

Compositions and Grades of lead. Malleability, softness, lubricity and coefficient of thermal expansion, all of which are quite high; and elastic modulus, elastic limit, strength, hardness, and melting point, all of which are quite low are related properties that account for the extensive use of lead in many applications.

Grades of lead Grades are pure lead (also called corroding lead) and common lead (both containing 99.94% min lead), and chemical lead and acid-copper lead (both containing 99.90% min lead). Lead of higher specified purity (99.99%) is also available in commercial quantities. Specifications other than ASTM B 29 for grades of pig lead include federal specification QQ-L-171, Canadian Standard CSA-HP2, and Australian Standard 1812.

Corroding Lead. Most lead produced in the United States is pure (or corroding) lead (99.94% min Pb). Called corroding lead because it exhibits outstanding corrosion resistance typical of lead and lead alloys.

Chemical Lead. Refined lead with a residual copper content of 0.04 to 0.08% and a residual silver content of 0.002 to 0.02% is particularly desirable in the chemical industries and thus is called chemical lead.

Copper-bearing lead provides corrosion protection comparable to that of chemical lead in most applications that require high corrosion resistance. Common lead, which contains higher amounts of silver and bismuth than does corroding lead, is used for battery oxide and general alloying.

Lead-Base Alloys Because lead is very soft and ductile, it is normally used Commercially as lead alloys. Antimony, tin, arsenic, and calcium are the most common alloying elements. Antimony generally is used to give greater hardness and strength, as in storage battery grids, sheet, pipe, and castings. Antimony contents of lead-antimony alloys can range from 0.5 to 25%, but they are usually 2 to 5%.

Lead-calcium alloys have replaced lead-antimony alloys in a number of applications, in particular, storage battery grids and casting applications. These alloys contain 0.03 to 0.15% Ca. More recently, aluminum has been added to calcium-lead and calcium-tin-lead alloys as a stabilizer for calcium. Adding tin to lead or lead alloys increases hardness and strength, but lead-tin alloys are more commonly used for their good melting, casting, and wetting properties, as in type metals and solders. Tin gives the alloy the ability to wet and bond with metals such as steel and copper; unalloyed lead has poor wetting characteristics. Tin combined with lead and bismuth or cadmium forms the principal ingredient of many low-melting alloys.

Arsenical lead (UNS L50310) is used for cable sheathing. Arsenic is often used to harden lead-antimony alloys and is essential to the production of round dropped shot.

Type metals: A class of metals used in the printing industry, generally consist of lead-antimony and tin alloys. Small amounts of copper are added to increase hardness for some applications.

Cable Sheathing: Lead sheathing extruded around electrical power and communication cables gives the most durable protection against moisture and corrosion damage, and provides mechanical protection of the insulation. Chemical lead, 1% antimonial lead, and arsenical lead are most commonly employed for this purpose.

Sheet: Lead sheet is a construction material of major importance in chemical and related industries because lead resists attack by a wide range of chemicals. Lead sheet is also used in building construction for roofing and flashing, shower pans, flooring, x-ray and gamma-ray protection, and vibration damping and soundproofing. Sheet for use in chemical industries and building construction is made from either pure lead or 6% antimonial lead. Calcium-lead and calcium-lead-tin alloys are also suitable for many of these applications.

Lead Pipe. Seamless pipe made from lead and lead alloys is readily fabricated by extrusion. Because of its corrosion resistance and flexibility, lead pipes finds many uses in the chemical industry and in plumbing and water distribution system. Pipe for these applications is made from either chemical lead or 6% antimonial lead.

Solders in the tin-lead system are the most widely used of all joining materials. The low melting range of tin-lead solders makes them ideal for joining most metals by convenient heating methods with little or no damage to heat-sensitive parts. Tin-lead solder alloys can be obtained with melting temperatures as low as 182 °C and as high as 315 °C. Except for the pure metals and the eutectic solder with 63% Sn and 37% Pb, all tin-lead solder alloys melt within a temperature range that varies according to the alloy composition.

Lead-base bearing alloys, which are called lead-base Babbitt metals, vary widely in composition but can be categorized into two groups:

- Alloys of lead, tin, antimony, and, in many instances, arsenic
- Alloys of lead, calcium, tin, and one or more of the alkaline earth metals.

Ammunition. Large quantities of lead are used in ammunition for both military and sporting purposes. Alloys used for shot contain up to 6% Sb and 2% As; those used for bullet cores can contain up to 5% Sb.

Additional recommended related articles: The following are available at: http://www.lasc.us/ArticleIndex.htm and http://www.lasc.us/ArticlesFryxell.htm

- CAST BULLET ALLOYS AND OBTURATION: by Glen E. Fryxell
- A FEW COMMENTS ON CAST BULLET ALLOYS: by Glen E. Fryxell
- THE "SIMPLE" ACT OF FLUXING: by Glen E. Fryxell
- HEAT TREATING LEAD - ANTIMONY - ARSENIC ALLOYS: by Rick Kelter
- LUBRICATING CAST BULLETS: by Glen E. Fryxell
- LEADING DEFINED: From Old Mid-Kansas Cast Bullet website (No longer in operation)
- LEAD SAFETY: by John Cox
- Alloying Antimony With Roto Metals Super Hard: by Rick Kelter

Endnotes

- Contributions by Glen E. Fryxell
- Stronger bullets with less alloying, by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, page 119.
- The Lyman Cast Bullet Handbook, Third Edition, page 43.

- Stronger bullets with less alloying, by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, pages 119 and 121.
- The Antimony Man, ANTIMONY MAN.
- Heat Treating Lead, Antimony, Arsenic Alloys, by Rick Kelter,
- The tin in your cast bullets by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, page 130.
- The Truth About Wheel Weights, by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, page 133.
- Stronger bullets with less alloying, by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, page 126.
- The Truth About Wheel Weights, by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, page 133.
- The Truth About Wheel Weights, by Dennis Marshall, The NRA Cast Bullet Book by Col. E. H. Harrison, page 133.
- Alloys for Cast Bullets, by Jerry Gonicberg, The Art of Bullet Casting, Wolf Publishing, page 86.
- Alloys for Cast Bullets by Jerry Gonicberg, The Art of Bullet Casting, Wolf Publishing, pages 85 & 86.
- KEY TO METALS, an industry leader in supplying lead alloys to industry worldwide.

The NRA Cast Bullet book by Col. E. H. Harrison referenced in the article is out of print. This book is of tremendous value to bullet casters and I can't help but wonder if enough emails and phone calls to the NRA Publications Dept. could prompt a reprinting of this exceptional reference. All of the books referenced from Wolfe Publications are currently available on DVD and CD. These are excellent books on bullet casting and well worth acquiring.

The Lyman Cast Bullet Handbook, third edition, this book should be on every bullet casters bench. In 2010 Lyman published the fourth edition of "The Lyman Cast Bullet Handbook".