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The international quarterly for the battery technology industry

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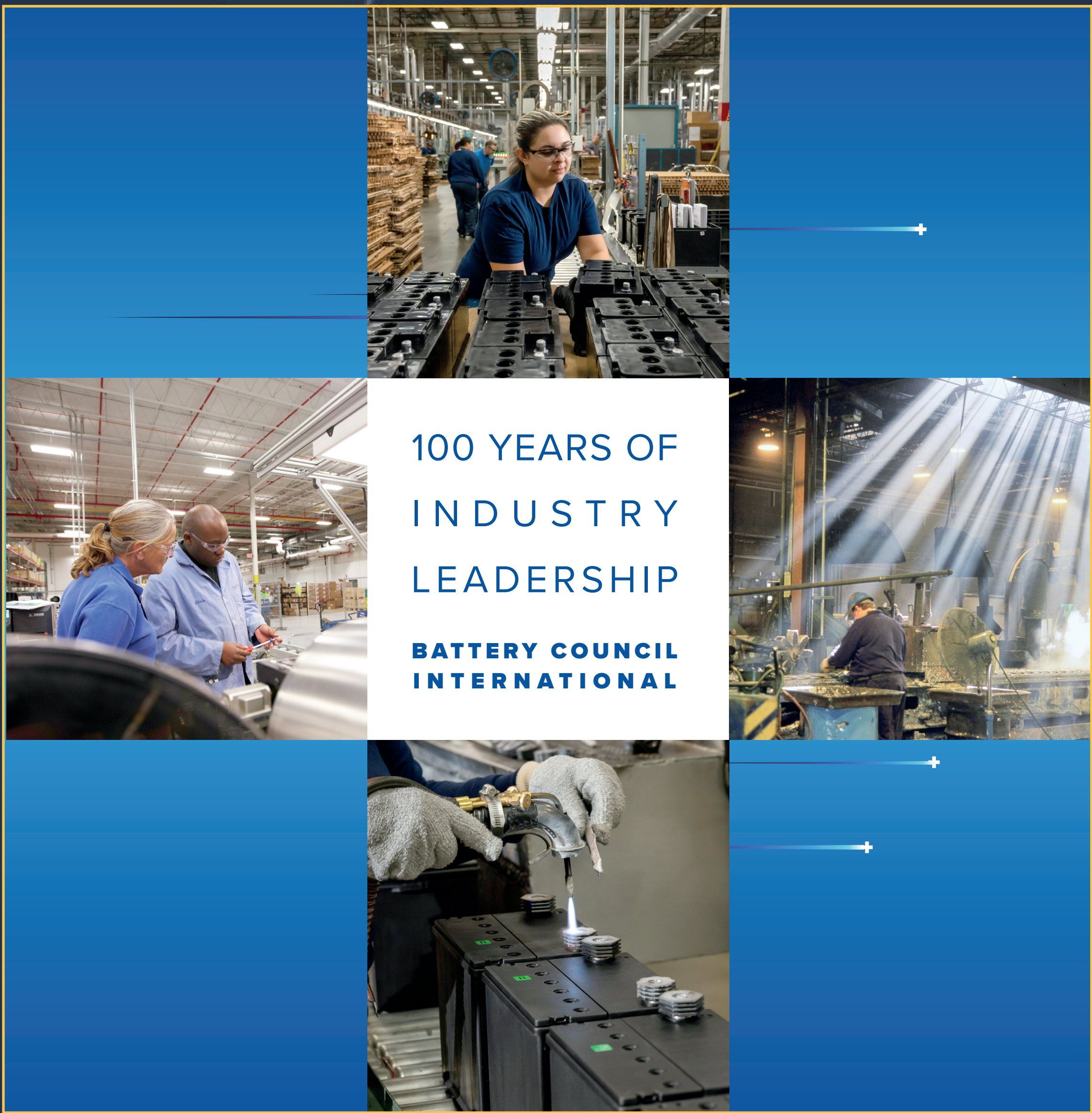

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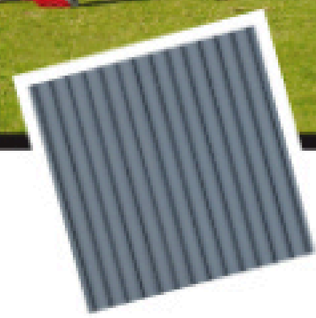

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BCI 2024 convention will be the event of the century!

It all started a century ago, when a small group of manufacturers met in Chicago to discuss the rapidly evolving energy storage landscape. The introduction of electric starters around that time had changed the nature of the budding automotive industry by creating a need for a reliable power supply in vehicles.

While this sparked a growth mega trend for U.S. battery firms, it also created a complicated product mix that caused headaches for businesses, consumers, and battery manufacturers alike.

On March 21, 1924, the National Battery Manufacturer's Association – the group that would eventually become Battery Council International – was formed with 25 official members. The new group standardized product dimensions to support the automotive industry's growth and developed voluntary safety standards to protect the industry's workers, among other accomplishments.

That mission lives on 100 years later, and will be front and center at the BCI 2024 Convention + Power Mart Expo in Fort Lauderdale, Fla., on April 21-24. One of the original missions of the Battery Council International was to bring sanity to an unorganized way of making products across the industry, and we continue to tirelessly support the safe and efficient production of energy storage solutions.

This year's convention will bring together more than 30 leading industry experts to share valuable insights on the battery industry's hottest topics. Attendees will hear forecasts on the future of energy storage in "The Golden Age of Batteries," learn about emerging industry trends, and get updates on compelling research already underway.

For the first time ever, BCI will host a fireside chat with four top CEOs who will engage with each other and take questions from the audience on the biggest issues of the day. Hal Hawk, President and CEO of Crown Battery Company; Chris Pruitt, CEO and President of East Penn Manufacturing; Dave Shaffer, Director, President and Chief Executive Officer of EnerSys Inc.; and Mark Wallace, President and Chief Executive of Clarios will put their heads together to provide commentary and insight you won't hear anywhere else.

And of course, the Power Mart Expo will provide an opportunity to do business and meet new customers. By popular demand, we're bringing you a bigger Power Mart Expo with a second full day of exhibits – and this year's trade show floor is already bursting, with a record number of booths and participants!

Last but not least, the BCI event will close with a Centennial Celebration to mark 100 years of history and the bright future of our industry. This once-in-a-lifetime event will feature door prizes, dinner, drinks and live entertainment from the Gin Blossoms.

The band has sold over 10 million records, and remains one of the most in-demand live artists from the 1990s. The 75-minute set will take place at our beautiful oceanside venue, the Fort Lauderdale Marriott Harbor Beach Resort & Spa – and will be exclusive to BCI conference attendees! You'll hear popular tunes including the band's Top 25 smash "Hey Jealousy" along with other hits "Found Out About You" and "Follow You Down."

Don't miss the event of the century at this year's BCI 2024 Convention + Power Mart Expo in Fort Lauderdale, Florida, on April 21-24.

bci BATTERY COUNCIL INTERNATIONAL | 100 YEARS

bciconvention 7

The best days of BCI are yet to come

By Roger Miksad, President and Executive Director of Battery Council International

The world is experiencing a battery-powered revolution, with rapid developments in transportation and energy storage that promise enormous environmental and economic gains.

That means the innovation and principles of product stewardship championed by Battery Council International and its members are more relevant than ever before. As we celebrate 100 years as a trade association, I am convinced that the best days of this industry are ahead of us.

Consider a recent independent economic analysis that estimates the U.S. battery industry powers roughly $8.1 trillion worth of domestic industrial economic output annually, or roughly 20% of the U.S. economy. All told, a staggering 48 million U.S. jobs are related to or reliant on the battery industry.

Sometimes small but always a necessity, batteries already power a huge share of the modern economy. And BCI's member firms and their employees are massive engines of growth for their local communities.

Since the association's founding in 1924, the ubiquitous – and too-often underappreciated – automotive batteries that have long formed the backbone of the battery industry have reliably powered nearly one billion cars and trucks in the U.S. alone. And advanced lead-based batteries are supporting the growth of reduced-mission and electric vehicles, and supporting 21st century industrial applications.

New and growing applications like grid-storage, EV fast-charge support, vehicle auxiliary power, and other areas are opening markets and unprecedented opportunities. Batteries of all types including lead-based, lithium-ion, flow, sodium-ion, and emerging battery chemistries are supercharging this transition to renewable energy sources and a more sustainable global economy.

BCI is proud to be a part of this mission of sustainability and innovation. We have a century of experience and expertise, and will continue to advocate on behalf of all battery manufacturers and recyclers going forward.

After all, it was not by accident that our industry and lead battery technology have thrived over the last century. Rather, it was through a continued commitment to improve safety and efficiency, as well as purposeful policies and an industry commitment to circularity.

With BCI's leadership, the U.S. industry built and currently operates an unparalleled collection-and-recycling system for lead batteries that is the envy of other products. For more than 30 years, lead batteries have been recycled at rates far outpacing any other consumer product. Lead battery recycling diverts hundreds of millions of pounds of lead and plastic from landfills annually and supplies the materials needed to manufacture new batteries. A truly circular economy.

BCI has also worked tirelessly to improve the safety and efficiency of battery manufacturing and recycling processes. Our industry was able to meet the energy needs of a changing economy and grow a domestic manufacturing base, all while improving its environmental footprint. That is a path that other emerging battery chemistries can achieve through the same hard work and dedication. It's this commitment to improvement that has allowed lead battery technology to thrive – even as other energy fads have fallen away in an ever-changing global economy.BCI stands ready to share its experiences with all stakeholders to achieve those goals.

BCI is particularly interested in sharing lead battery recycling's core strategies with stakeholders in other battery chemistries so they can learn from our success. These include practices such as consistent labeling standards, widespread free consumer collection opportunities, prohibitions on improper disposal, and industry-funded transportation and processing networks.

Energy storage is one of the most rapidly evolving industries in the 21st century. And in the coming years, the pace of change may only accelerate as new technologies and advances in existing technologies move out of research labs and into the mainstream economy.

The quest for constant improvement is a hallmark of our industry. Since 2016, our annual convention has featured the BCI Innovation Award that recognizes innovations within the industry on sustainability, safety, cost, performance, uniqueness and value. And I'm confident that with sound policies and industry initiative, we can replicate the circularity success of lead batteries across additional chemistries. BCI is eager to support the future of energy storage with our rich experience, respect across the industry and with regulators, and a history of success.

At the BCI 2024 Convention + Power Mart Expo on April 21-24 in Fort Lauderdale, Florida, we will formally gather to discuss the dynamic state of our industry industry. But we'll also mark the 100th anniversary of Battery Council International as the leading energy storage trade group.

Registration is on pace to smash records, and it's sure to be an anniversary event to remember as we recognize some of the great people who helped build our industry over the last century and celebrate our success.

But the BCI 2024 Convention isn't just a victory lap. We'll keep looking to the future, too – because the brightest days of this industry lie ahead.

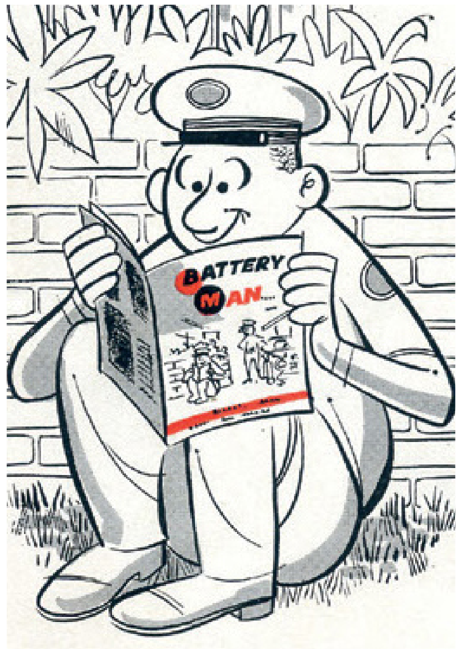
It's an exciting time for this industry as we look to the future. We hope to see you in Florida to mark our centennial anniversary. And more importantly, we hope you'll continue to place your trust in BCI in the decades to come.

thebatteryman

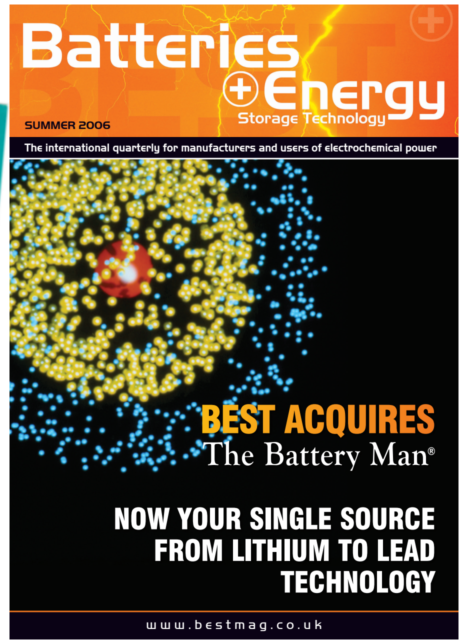
In September 1921, the first issue of the automotive electrical industry's independent trade journal *The Battery Man* is published, offering expert advice for members of the battery industry.

As the battery manufacturing industry took off in the early 1920s, a small trade journal began circulating among those who worked in "the automobile storage battery and electrical field."

The first issue of *The Battery Man*, an independent publication founded by Overton W. Pendergast Jr. and Al Hemberger, appeared in September of 1921. Every month until 2005, when The Battery Man ceased publication, members of the industry received invaluable information, expert advice, and more in the pages of the periodical. For more than eight decades, it was recognized as a go-to resource that served the battery manufacturing industry worldwide.



In 2006 *The Battery Man* was acquired by, and incorporated into, *BEST magazine*. The spirit of *The Battery Man* lives on as experts from the industry continue to deliver invaluable information and expert advice on lead-acid batteries alongside new battery chemistries and energy storage technologies that will help take the industry and the planet into an energy-secure future.



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- **PowerFill™** – A cutting-edge enhancer for AGM separators for VRLA batteries used in data centers, industrial trucks, aerospace and other systems that require uninterrupted power supplies.
- **Pasting Paper** – Advanced AGM pasting paper products that enhance the performance of batteries used in light passenger vehicles, motorcycles, commercial trucks, data centers, energy storage systems and telecommunications networks.
- **PA10-6** – A microglass fiber additive that is used as a processing aid in lead battery assembly, contributing to improved battery performance and life.

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The pull of gravity casting for industrial lead-acid batteries

Technical Editor Mike McDonagh examines gravity casting – machinery, mould designs and alloy materials.

Since last writing on this subject, the emphasis for lead-acid manufacturers has been to transition from book-mould gravity casting to rolled-strip continuous methods. The reasons for this are chiefly to automate and speed up the grid manufacturing to match the pasting speeds of that next process. However, it is also to reduce the lead-grid thickness and therefore the lead content of the grid.

Apart from, and hopefully as well as, lead savings, it can enable the use of a higher number of thinner grids in the same group size to maximise the plate surface area. This can drastically improve the cold-cranking performance of SLI batteries.

However, current strip-casting technologies place restrictions on grid design that, for some industrial applications like traction, UPS, standby etc., can reduce battery performance, life and potential lead savings.

For those industrial batteries that undergo either deep cycling or float-charge conditions, the grid design and lead distribution within the plate do play a critical role. Correct grid design can prevent or reduce grid growth, paste shedding, a shortened life via grid corrosion and a high internal cell resistance. For the present at least, gravity grid casting is still the go-to option to obtain the optimum design features for many industrial battery grids.

Having established that gravity book-mould casting is still a requirement in a significant number of applications, we will look at both the equipment and materials used for the majority of the battery types in this sector. There are two distinct battery designs: those with tubular positive plates and those employing flat positive plates to meet their market requirements. For this article, only the machinery, mould designs and alloy materials adopted by the industry for book-mould casting will be examined.

The lead alloys most widely used are straightforward: lead-calcium-tin and lead-antimony form more than 99% of the grids used for industrial flat plate battery designs. There are still some Plante versions that use pure lead, and the Enersys technology will be covered in a future article.

Standardised equipment

Book-mould gravity casting equipment is fairly standardised. ***Fig 1*** is a typical lead alloy grid casting machine used for many decades by lead-acid battery manufacturers. This consists of a melting pot to hold the lead alloy in the molten state, a pump and a feedline to fill a ladle, which pours the molten alloy into a split mould. The mould freezes the alloy as rapidly as possible before ejecting the formed grid onto a transport belt.

The castings drop onto a holding plate where they are cut to size using a guillotine. This operation also removes the mould pouring gate left on the top of the casting. The groups or stacks are then placed onto a rack by the machine. The operative transfers the grids in piles onto an examination table. After QA checks, and possible trimming of excess flash, they are stacked onto a pallet for storage and age-hardening before the next process. ***Fig 2*** shows a typical gravity casting shop in a well run lead-acid battery factory.

Over the last few decades, there have been significant changes in lead alloys used for battery manufacture. These are due to both processing and market requirements. ***Table 1*** gives a breakdown by market sector. Because of their very different casting properties, it is necessary to describe the two main alloys in use before describing the controls and equipment required to produce grids. The more common specifications for the alloys are given in ***Table 2***. In each case, the principal reason for the addition of calcium and antimony is to harden the soft pure lead sufficiently to enable the plates to withstand the subsequent processes.

Other minor additions either enhance the hardening effect or serve to improve the performance or durability of the grids in service. The alloy hardness and stiffness are

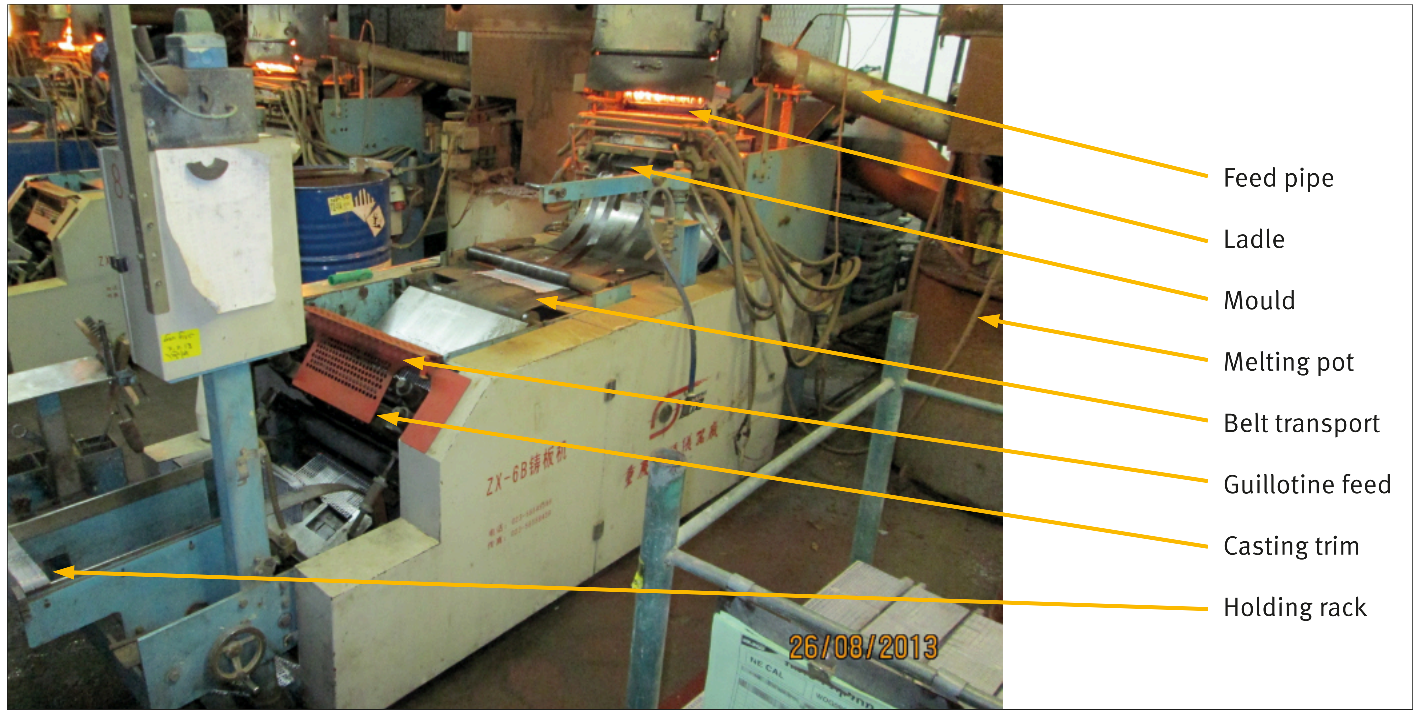


Fig 1: Typical book-mould gravity casting machine.

Fig 2: Well run gravity casting shop in s lead-acid battery factory.

Engine Starting	Pb-Ca(Sn)	Good high-rate performance
Automobiles		Low gassing rate
Trucks		Low self-discharge rate
Lawn Mowers		Poor recovery from deep discharge
Recreation Vehicles		
Aircraft		
Motive Power	Pb-Sb	Good cycle life
Materials Handling		Higher gassing rate
Airport Tugs		Higher self-discharge rate
Golf Cars		Good deep-discharge recovery
Standby Power	Pb-Ca(Sn)	Good high-rate performance
		Low float currents
		Low water loss
		Low maintenance
	Pb-Sb	Good choice for applications where duty cycle involves cycling
Valve-Regulated	Pb-Ca-Sn	Good high-rate performance
		Some cycle capability
		Low water loss
		Low maintenance

Table 1 (above) Table 2 (below) Typical grid casting alloy compositions. (During production, errors appeared in Table 2. The correct table is shown below. Many thanks to Doug Lambert for spotting this.)

Element	Lead calcium-tin	Lead calcium-tin-aluminium	Lead antimony
Calcium	0.05–0.11% Hardening agent	0.05–0.11% Hardening agent	
Antimony			1.0–9.0% Hardening and fluidity agent
Tin	0.5–2.0% Fluidity, mechanical and electrochemical properties	0.5–2.0% Fluidity, mechanical and electrochemical properties	0.05–3.5% fluidity and metal joining properties
Aluminium		0.015–0.025% Anti oxidant to prevent element loss in the casting process	
Arsenic			0.05–0.23% Aids in the age hardening process
Selenium			0.015–0.035% Grain refiner
Copper			0.02–0.05% Grain refiner
Sulphur			0.005–0.03% Grain refiner
Silver	0.01–0.02% Used mainly in positives to enhance performance and cycle life, controversy as to effectiveness	0.01–0.02% Used mainly in positives to enhance performance and cycle life, controversy as to effectiveness	

directly related. Pure lead is too soft to process through standard lead-acid battery manufacturing. Both antimony and calcium give initial stiffness followed by age-hardening where these elements or inter-metallic compounds precipitate out within the grid structure and grow with time.

This introduces strain energy into the lead alloy metallic lattice, which restricts the lead molecules from easily moving. This resistance to atomic movement in the lattice translates into rigidity and hardness of the cast grid alloy. It starts with lead-antimony (Pb-Sb), the backbone of the lead-acid battery industry for over a century.

Lead-antimony alloys

The principal reason for adding antimony is to harden the grid. This serves the dual purpose of enabling the pasting and assembly processes without damaging the plates, and

also increases the yield and creep strength of the grid in service, which reduces grid growth during charging.

This delays the point at which the positive grid may expand sufficiently to touch the negative strap. It is this contact causing a short circuit that effectively ends the life of the battery. UPS and deep cycle applications, where the charging regime will severely corrode the positive plate causing the grid growth, are particularly susceptible to this failure mode.

The amount of antimony in these alloys has reduced significantly over the half century that I have been in the industry; from 11.5% down to less than 2% in many current applications. The driving force for the reduction is two-fold: antimony is expensive and it also lowers the hydrogen overvoltage on lead. This lowering of the hydrogen overvoltage increases water loss through electrolysis, and escape of hydrogen via gas evolution. This has meant a lot of modification to the casting equipment over the decades to cope with the very different processing requirements of modern lead-antimony alloys.

There has also been considerable metallurgical progress in alloy composition – to mitigate the loss of strength and ease of casting properties – resulting from this reduction. To understand this, we need to examine the lead-antimony phase diagram. ***Fig 3*** represents the lead-antimony system which shows the relative proportions of alpha (lead-rich phase) and beta (antimony-rich phase) as a function of antimony in lead concentration on the X axis and temperature on the Y axis. This is described as a eutectic structure.

The main characteristics of this shape of phase diagram is that there is a point, the eutectic composition,

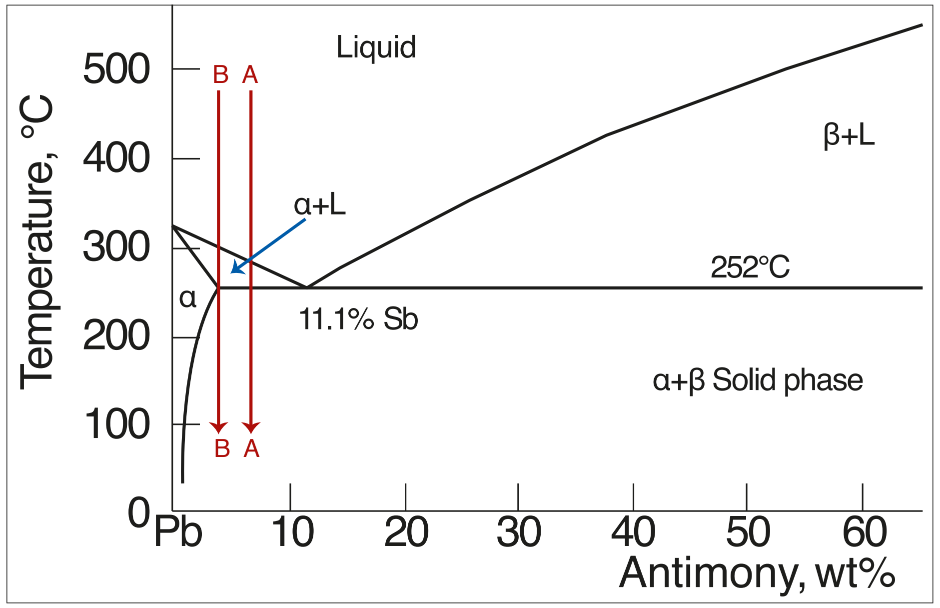


Fig 3: Lead antimony phase diagram, lead-rich end.

of 11.1 wt% antimony on this diagram, where the liquid alloy will be directly converted into a solid when cooled below the eutectic temperature. At this composition the flowing metal alloy is extremely fluid right down to its freezing point of 252°C. At antimony concentrations less (or more) than 11.1% antimony, there is a range of temperature during which solid and liquid co-exist in equilibrium.

For low antimony alloys, when poured into and moving through the pathways of a mould, there are particles of precipitated alpha phase that are growing larger as the alloy cools. These growing particles are not smooth balls: they have a dendrite (tree-like) structure that entangles and impedes the liquid flow (line A-A). The length of time and the size of these dendrite crystals increases the lower the concentration of antimony (line B-B). This makes the situation worse and, in the early days of low antimony alloys, defects such as missing wires, internal grid porosity and frame sinkage were common. There was also the minor issue of having very weak grids due to the lower hardening contribution from the lower antimony content.

Secondary metal additions

The answer to most of these issues was secondary metal additions. The two principle secondary ingredients (after a couple of decades of trials) have been isolated to arsenic (As) and selenium (Se). Arsenic was the principal ingredient that enhanced the alloy hardness (Cottrell atmosphere effect, for the metallurgists) and selenium, which reduced the spikey dendrite alpha phase dendrites to smoother, smaller, and rounder crystals (surface energy reduction, or wetting).

These were great innovations, but it did mean that the casting process had to be radically overhauled. The first point is the higher solidification temperature of the lower antimony alloys. All temperatures, from pot melting through feedpipe distribution and ladle pour, to mould temperatures, had to be raised. This meant that oxidation rates increased and more secondary elements were

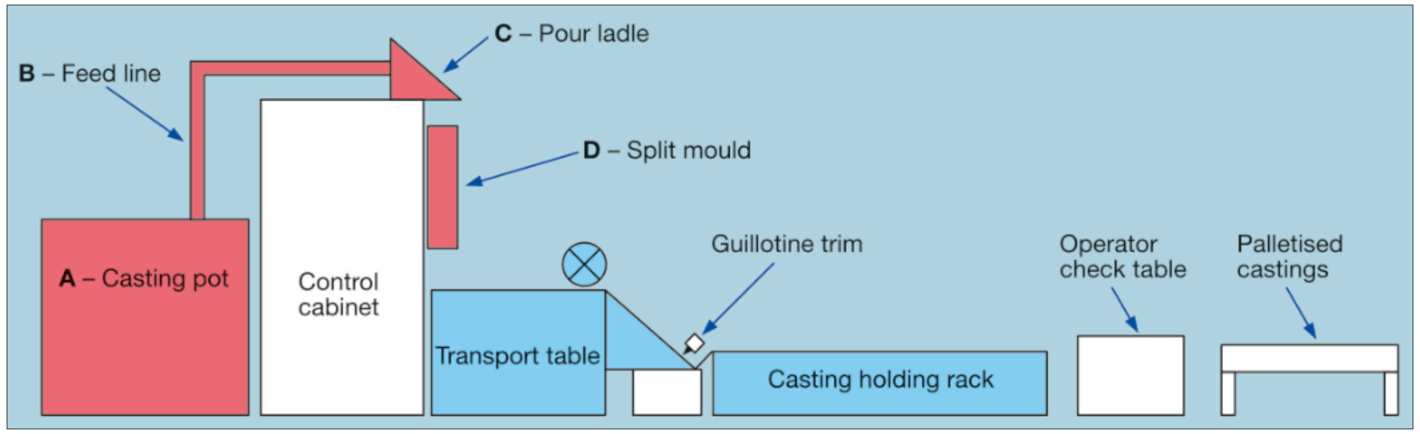


Fig 4: Casting machine schematic

lost to the increased dross build-ups in the pot and feedpipes. ***Fig 4*** is a schematic of a typical gravity casting machine with a cooled split mould. The sectors that needed to have higher temperatures are shown as A – casting pot, B – feed line, C – ladle and D – mould.

Typical operating temperatures at each point for a 1.2-1.5% antimony alloy are given in ***Table 2***. The critical points listed above are areas which have to be precisely temperature controlled and made impervious to air ingress. The control of temperature is paramount in order to reduce dross build up in the ladle, feedpipe and on the melting pot. There are different reasons for dross creation for each of these zones.

However, the effect is the same, as secondary metals will be lost and lead scrap created. It is counter-intuitive to non-metallurgists, but a low temperature in the feedpipe will lead to more dross and loss of some secondary elements. This is because these secondary elements have low solubility in lead and will precipitate out as solid oxides where the temperature drops below the solubility limit for a particular concentration. Selenium, for example, is chosen as a grain refiner, in part because it will precipitate out in the molten alloy and form seed crystals for alpha-phase particles to nucleate in abundance.

This inhibits the unrestricted growth of a few particles that are effectively in a large swimming pool of supersaturated lead-antimony alloy. For the exposed areas, higher temperatures will create lead dross due to air contact. The ladle is particularly vulnerable to this and should have an inert or reducing atmosphere. Dross creation at this point also removes secondary elements, particularly tin, which is essential for corrosion resistance as well as alloy fluidity in casting.

For the melting pot, both conditions that cause dross by oxidation and loss of secondary elements due to low temperature, have to be simultaneously observed. The operating temperature of the melting pot is therefore a compromise to minimise both of these consequences.

Likewise, the mould has the function of both ensuring good metal flow to fill the mould but also rapid cooling to ensure high productivity rates. The evident compromise here is achieved by coating the mould with an insulator. The coating is applied by spraying a cork and silicon suspension onto the mould that forms an adherent layer powder when dried. The precise thickness and composition provide the correct balance between heat retention to ensure fluidity, and heat extraction for rapid solidification and optimum output.

The type of coating can be determined using Ficks law for heat rather than material diffusion

$$Q/t = kA(T_h - T_c)/d$$

Q is the heat transfer with time t (rate of transfer)
K is the thermal conductivity
A is the area
T_h and T_c are the hot and cold surfaces – in this case the cork surface and the steel mould surface respectively
d is the distance or thickness of the coating.

Lead-calcium alloys

As the demand for higher productivity, better lead and process economy, improved CCA in SLI batteries and less gas evolution in VRLA designs increased, it became obvious that an alternative lead alloy to lead-antimony was required. The main driving force for change was the advent of strip rolling methods to produce grids.

Lead-antimony is a eutectic alloy. As described, it has both solid and liquid in equilibrium during the cooling process. This is an anathema for metal rolling as it results in many casting defects, most notably hot tearing. Lead-calcium was introduced and has a peritectic structure on cooling. This enabled very fast strip production. However, a Pandora's box of other problems (a future article) was opened up.

Early lead-calcium alloys were reported to suffer from either catastrophic corrosion or PCL (premature capacity loss). However, these were gradually overcome and metallurgists, notably David Prengaman, came to the rescue to provide the answers and solutions. These problems were cured by secondary additives, mostly tin (antimony) and processing controls.

Readily adopted for grid gravity casting

Against this background, the lead-calcium alloy was readily adopted for grid gravity casting, initially for negatives but later, as alloys improved, also for positives. However, as mentioned, it has very different solidification and processing properties that needed to be addressed. Typical levels of calcium are 0.65-0.85 wt% for the positive and 0.09-0.13 wt% for the negative grid ***Table 2***.

However, it is important to remember that these are the values that should end up in the cast grid. Due to oxidation losses (described below) the specification for the purchased alloy may have higher levels. The precise specification depends mostly on the processing conditions and procedures of particular manufacturers.

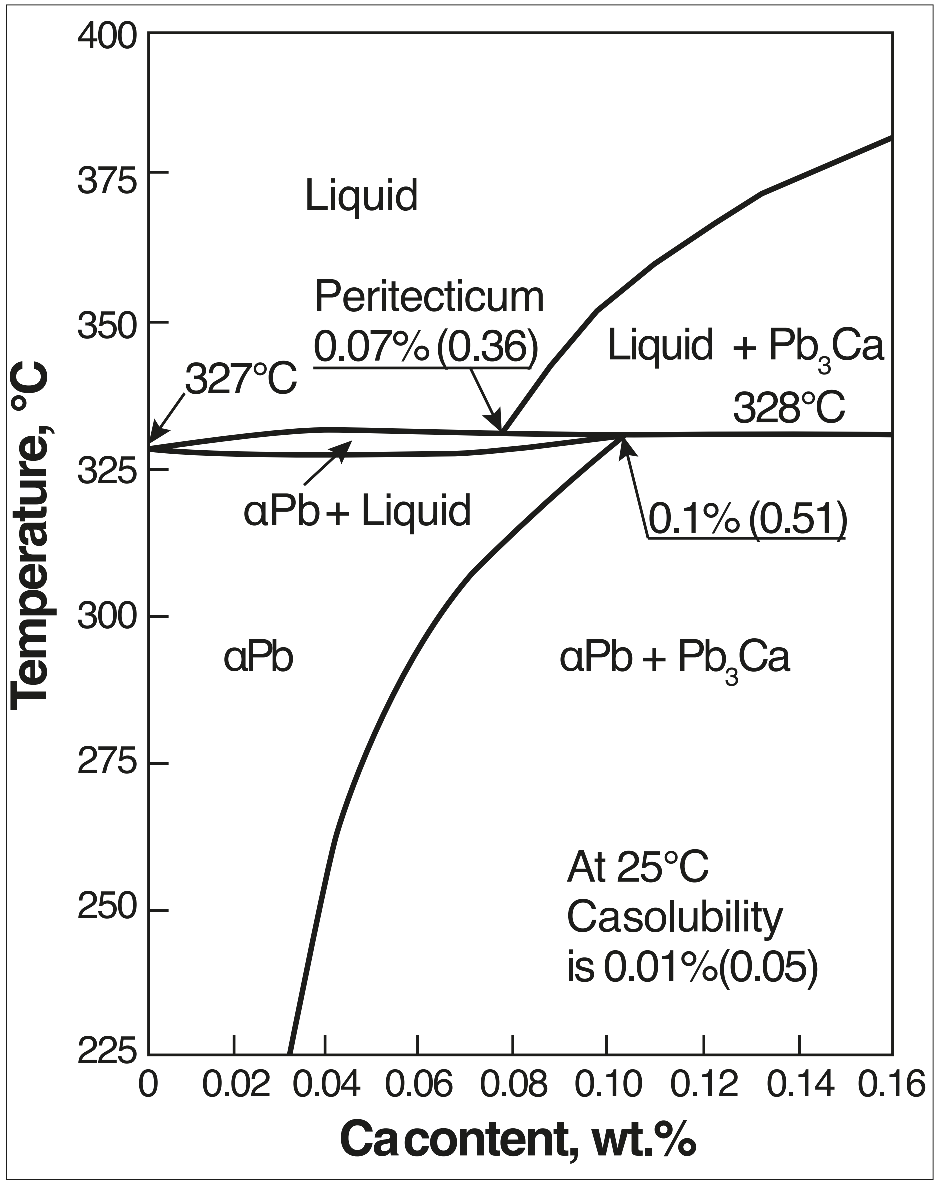


Fig 5: Lead calcium phase diagram, lead-rich end

Fig 5 shows the calcium-rich end of the lead calcium peritectic phase diagram. From this it can be seen that there is no extended liquidus line, nor concentration value where there is a straight transition from liquid to solid. This means the problems associated with solid and liquid being in equilibrium during freezing (casting) of the alloy, are more or less avoided. You can also see that the temperature range for the solid solution alpha phase is higher than with the lead-antimony system, the alpha phase existing completely as a solid below the transition temperature, with a solid-liquid equilibrium phase spread of only 2°C. In plain terms, for lead-calcium alloys, the flow and solidification characteristics when filling a grid mould are very different when compared with lead-antimony alloys.

It means no hot tearing tendency, no sinkage in areas of differing cross-section and casting rates should be faster. However, there is a problem with handling as the grid is very soft and the age-hardening process is a little more difficult. For this reason, gravity casting machines should be equipped with air cooling on ejection of the casting, cooled powered rollers to transfer the grid to the guillotine, and again air chilling when on the rack.

Since this is gravity casting only, we will examine the process and equipment requirements necessary to address the correct conditions to prevent loss of the additives – and the implications of not doing so.

Fig 5 shows a vertical line that traverses the liquid to solid-state phase at a concentration of 0.08% calcium. By following this downwards (cooling) we can map the phase changes as the alloy freezes. The approximate sequence is:

1. at a pour temperature of 500°C the alloy is completely liquid and swirls round the frame and backfills into the wires in less than two seconds

2. during the filling process, the alloy begins to nucleate solid particles a few microns in size at the lead surface in contact with the cooler mould face. These are swept up in the flow and form a thickening sludge, which fills the mould cavity and solidifies

3. the mould is filled before the solidification temperature at around 321°C. The alloy is relying entirely on superheat introduced in the ladle, to keep the alloy temperature far enough above its melting point, to maintain sufficient fluidity to fill the mould. The nucleating grains have grown in size and are roughly spherical and sometimes directional, emanating from the grid/mould interface. There is no after-flow of low melting point liquid between the grains, which are packed together, separated only by grain boundaries.

As mentioned, the first lead-calcium alloys had two problems – corrosion and PCL. For gravity casting, PCL was a predominant problem. Accepted wisdom at the time put this down to a non-conducting barrier layer between the AM and the grid metal that enormously raised the internal resistance, making the battery effectively useless.

However, the metal tin, when added in high concentrations to the positive grid, was the saviour of this alloy. Simply put, it enabled conduction through the lead compounds that form between the grid and active material on discharge. For this reason alone, the preservation of tin in the lead casting pot and throughout the journey to the grid mould, is crucial.

Machine settings

From these descriptions it is evident that there are processing differences between lead and lead-calcium alloys when gravity casting. The chief difference for the operator is the temperature settings.

Table 3 gives guidelines for the temperatures required for each stage of casting from the lead pot to the mould for both alloys. The actual temperatures used in casting may vary from those indicated depending upon the design of the casting and the equipment used. However, as a general rule, the use of grain refiners requires higher pot temperatures and the feedlines and ladles must also be kept at correspondingly higher temperatures than is the case for lead-casting.

Unfortunately, excessively high temperatures in the lead pot can increase the production of dross and increase the rate of secondary element loss through oxidation. Too low a temperature and the grain refiners precipitate out and float to the surface. Feedpipes can also jam up in any cold spot where secondary elements and their oxides will precipitate out as solids. They will form a very hard crust that adheres to the inside of the pipes and is a nightmare to remove. For the pot, the operating temperature is usually a compromise between maximising the concentration of secondary elements in solution and minimising their loss through surface oxidation.

The chief culprit to consider for loss through oxidation is tin in both alloys. This is mitigated in three ways:

1. addition of a sacrificial element, aluminium, to form a protective oxide on the pot surface to minimise surface oxidation in the melting pot and ladle

2. minimise surface agitation and keep exposed surfaces under a controlled atmosphere

3. have a procedure to remove dross from the pot.

Modern casting alloys are a complex mixture of additives that all play a distinctive role in the casting process and/or determining the electrochemical properties of the battery in service. Dross on exposed lead surfaces is a serious problem. It is formed by the oxidation of the surface of molten lead alloys that are exposed to the atmosphere. The method used for the removal of dross is a critical factor, as secondary elements that assist in grain refining and enhance the performance of the lead-acid battery can be removed during the procedure.

This may drastically reduce the concentration of beneficial secondary elements if the procedure is incorrect. Calcium is easily oxidised at the lead surface. Once calcium oxide is formed it is almost impossible to reduce this back to calcium and return it by dissolution into the lead alloy. Tin loss is also attributable to this mechanism. It forms Sn_xO_y compounds at the melt surface which float and get incorporated into the dross, which is subsequently removed.

When removing dross there are important rules to follow:

- agitation of the surface should be kept to a minimum
- there should not be an overflow return system from the ladle
- the ladle should be kept in an inert or reducing atmosphere
- the dross should not be removed more than once per shift if possible
- the dross should be stirred back into the lead mass before removal
- only dross as a powder should be removed. Sticky metallic residues below the powdery layer have high concentrations of most of the secondary elements ***Fig 6***.

Table 3: Gravity casting conditions for different alloys. (During production, errors appeared in Table 3. The correct table is shown below. Many thanks to Doug Lambert for spotting this.)

Process	Pb-Ca-Sn	Pb-Ca-Sn-Al	Pb-Ca-Al	Pb-Sb 1.6 – 5%	Pb-Sb 6 – 11%
Melting pot	470 – 510*	480 – 540*	480 – 540*	450 – 500	430 – 480
Feedline	470 – 520	480 – 540	480 – 540	450 – 500	440 – 480
Ladle	450 – 520*	480 – 540*	480 – 540*	450 – 510*	440 – 480
Upper mould	160 – 170	160 – 170	160 – 170	140 – 160	120 – 150
Lower mould	190 – 210	190 – 210	190 – 210	170 – 190	160 – 180

**Vapour pressure of lead becomes high above 500°C. Air extraction and filtration should be suitable to prevent increases in lead-in-air values.*

Typical condition of melting pot for Pb-Sb gravity casting

Fig 6a: Blockage of returned castings due to oxide (dross) build up on the surface of the molten alloy.

Fig 6b: Clean lead surface exposed after dross removal. The sticky surface layer contains many of the additives that assist the casting, age hardening process and properties of the grid.

Fig 7: Typical dross resulting from over enthusiastic removal of surface oxide. Contains tin and other added elements that should not be removed from the alloy.

Most operators prefer to see a clean surface as this enables the returned trim from castings to slide easily into the molten lead surface. This in turn keeps the return chute clear and prevents blockages from jamming up the moving parts of the machine ***Fig 7***. The amount of dross removed must be recorded and weighed and the concentration of key elements in the pot, such as calcium and tin must be monitored each day. This will enable the manufacturer not only to control the losses but also to calculate and monitor the concentration of secondary elements to include in the alloy specifications.

Three critical aspects

In summary, there are three critical aspects to getting the best from the standard alloy specifications in terms of ease of manufacturing and in service performance.

1. retaining the primary alloying elements, calcium, antimony, and tin throughout the casting process to maximise their concentration in the grid
2. ensuring that secondary alloying elements used as grain refiners or age-hardening agents are retained from the melting pot through to pouring into the mould
3. temperatures at each stage of casting, from the melting pot, through delivery pipes to the ladle and then the mould, are set to minimise precipitation of secondary elements or compounds within the lead transport system of the casting machine.

To ensure trouble-free processes, good mechanical and chemical properties of the grid and economic production, it is necessary to keep firm control of temperatures at each stage of casting. This should be combined with defined drossing procedures and correct cork-spraying methods.

Investment in calibrated temperature-measuring equipment and improved tools for removing dross is highly recommended and will have an immediate impact not only on the quality of the grid and the battery, but also the cost of the process. ⊕

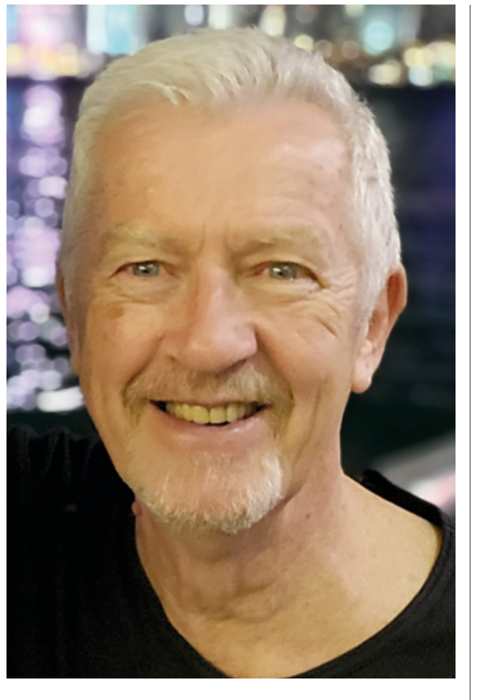
The reluctant battery man who imagined batteries were boring

Mike Dunckley is a battery industry veteran with almost 40 years' experience as a marketing and strategic director for global companies. His recent term as EMEA MD for Leoch ended in September last year. His role was primarily to spearhead their global marketing ambitions. Currently he is working on an energy-based project that draws together an international consortium of companies. *BEST* technical editor Mike McDonagh met him to learn more.

Mike Dunckley is a battery industry veteran with almost 40 years experience as a marketing and strategic director for global companies. Last year he was appointed as EMEA MD for Leoch, primarily to spearhead their global marketing ambitions. As a personal friend of mine for all of his time in the lead-acid battery industry, I know that he has a unique, critical and far-reaching perspective on the global battery market and its trends. In this interview I ask him to expound on his views of the direction that the battery market is headed.

BEST: We have known each other throughout your time in the lead-acid battery industry. I have always regarded you as having a unique perspective on the battery industry. Can you describe something of your background and what got you into this business?

Mike Dunckley: I came into the battery industry almost by accident. After studying graphic design at college, I quickly moved to account management. In the advertising industry, you get involved in many



different industries and business situations. My experience was mostly in the UK and in the 1980s covered banking, retail, industry and much more.

It was a demanding profession with long hours, working with senior managers and developing marketing-based business solutions. It was all about creativity, learning about a company, positioning it, and communicating a message. I rapidly progressed in this industry and eventually became a PR director for one of the offices of the international McCann Ericsson agency.

The battery industry found me. I was contacted by a local battery company. They were merging two companies in a month's time and had not thought out the communication and branding issues for international and external communication. Together with my agency team, we developed a launch event and a communication rationale. This was good training as I learned that one of the biggest aspects of merging or buying companies is integrating people.

After the launch event, the new managing director of the venture continually contacted me to join the new company and for a long time I declined the offer as I thought that moving to the battery industry was a rather boring opportunity. Boy, was I wrong.

Since we worked together in the 1980s at Hawker Siddeley, we have worked for different organisations. Please give a brief summary of your work, including the companies you were engaged with.

Growing up on, working and managing a farm gave me a great work ethic. I have always believed that work is an important part of who we are and what we contribute in life. I have always tried to do the best. My background is too long to describe here, except to say that I progressed through a series of steps from salesman to manager, director roles, then managing director and board member. Some managers get catapulted into senior positions today without having covered all the bases. This can be a weakness in my view as it's important to have real experience, not just something from a classroom or book.

As you pointed out, we met when we both worked for a division of a famous UK group, Hawker Siddeley. When I joined, I was recruited into the new battery venture, which was called Oldham-Crompton. I soon learned that the venture was a division of HS and that there were several battery companies, including operations in France and the USA. The group was quite small at that time and covered markets including automotive, traction, stationary, rail and military. The group also had two companies making lithium.

Having ended my career in advertising, I transitioned from my general marketing role at director level, to being the marketing manager in the newly merged company. All my ex ad-industry colleagues saw this a step backwards. They were right of course. But my new role was as challenging as it was interesting. I was now directly involved with manufacturing and learning to be part of a business that had a turnover approaching £100 million ($127 million).

Within months of starting, I met the newly appointed divisional chief executive of the battery group. His role was to bring the group together and manage its growth. However, a battery business was not considered to be compatible with a world famous engineering group like Hawker Siddeley, which had a strong history in the UK, tied to engineering and aerospace. Subsequently, the battery division was buried inside the larger portfolio of famous companies.

Within a year of joining the group the new chairman continually allocated me to special projects. My direct boss did not approve of my involvement in confidential work. This unfortunately led to my having several different roles inside the same job description. This situation has occurred too often in my career and was unwelcome. The chairman and I were both new to the industry and together we began to map out the market and start to form a plan to develop this relatively small group within Hawker Siddeley. This was a seminal moment in my career, leaning on my marketing knowledge, learning about strategy and the development and managing of a portfolio of companies.

What do you think you brought to your various roles that these companies benefitted from?

Today, we are surrounded by business trends and people telling us how to build companies. You can read a million books (and I have), but nothing compares to the experience of being in the business and getting involved in the everyday issues. It is not only about the products a business makes, it is knowing the market. This is all about the customers, and understanding the macroeconomics of the world.

It also about envisioning people and bringing them with you. I believe that I have a unique skill: the ability to absorb and understand all the complexity of issues, people, markets, economics and new trends, then combine them to enable clarity for the direction a business should take.

The next skill is the ability to communicate all those issues, facts and opportunities to a team, a workforce, a group, why a particlar direction is correct. The term we use today is vision. If you can do it successfully then you can motivate people. If we can find meaning for our role in even a part of that vision, then there is no greater motivation. Many senior managers don't understand this.

What would you say have been the most significant commercial changes during the time from when you began until now?

In my 30+ years in industry the speed of change has been dramatic. I entered the industry at the end of an era of national companies that dominated their local markets. Business was conducted through strong local relationships. In general, Brits bought from Brits, French from French and so on. There were strong cultural barriers. This changed with communication advances. The mobile phone, cheaper travel and the internet all lowered these barriers, and international competition increased.

Regarding technology, when I came into the industry lead-acid had a virtual monopoly. Lithium only existed in primary cells. There were some specialist formulations for military and other special applications, but in general it was all about lead-acid.

Today, lead-acid has been dramatically challenged. For the moment that challenge is lithium but there are many other battery chemistries on the way and there are many global research and development programmes that are transforming the industry. What is unique about these developments is that they are being driven by a global emergency to transform society from oil and carbon-based fuels, to renewables-generated electric power.

How has that impacted on the industry?

The biggest change has been that the customer now has more scope to purchase goods from many sources. This has been good for the market and particularly customers, as it has sharpened competition. Like the industry itself, customers have gained knowledge and raised their expectations. Quality and service have improved, and in general the industry has raised the bar. We are also in a golden age when every person, everywhere talks about batteries. Our industry is no longer a grudge and commoditised purchasing decision, but something that is critical to the future. I am personally excited to be still involved in many of these developments.

What about the battery technology developments? What effect has that had on lead-acid battery manufacturers?

There is no doubt that the lead industry is under pressure. The lead-acid battery used to operate almost with a technology monopoly. The chemistry and the industry as a whole, have done a good job. In particular the record on recycling is impressive, which all of the new chemistries will struggle to match. Manufacturing processes have dramatically improved quality, and I think the battery manufacturing equipment industry has done a great job in improving equipment and industry throughput.

As we all know, there are lots of initiatives ongoing in the industry to improve the performance of the lead-acid battery chemistry. All of these are designed to considerably enhance lead-acid battery performance, including better cyclability and energy density.

In my view, lead-acid thin plate batteries have always been an industry benchmark. My own former group saw the opportunity of this technology in the 90s and invested significantly. What has surprised me is the failure of the industry to understand, or even see the opportunity to create a winning product.

A few tried, such as Northstar, and were to be commended, but only Enersys has truly understood and taken advantage of the chemistry.

Recently other companies are starting to see the potential. Hoppecke for example and others are following. But it has taken more than 20 years to realise this. It is interesting to note that the performance improvements of pure lead come from the mechanical design rather than enhancements to the chemistry itself.

Do you think it is right to continue putting effort and resources into improving lead-acid battery chemistry?

This is a very interesting question. We must recognise that the world operates in a different way. We are moving into a world – for good or bad – of artificial intelligence (AI). We are already living in a highly digitised and connected world. We all want access to instant information, anywhere and in real time. This is the biggest challenge for many battery technologies. Customers want to be connected to their investments to check performance and anticipate problems.

The biggest challenge for lead-acid batteries is that they are 'passive'. In other words, they are fit and forget, and work until they fail. However, they are not connected electronically and cannot be monitored in real time. This is a problem. I believe that the lead-acid companies that are going to survive will start to pay more attention to this extra-altilium innovation. There are many things that can be done. Improved charging performance, customer service etc.

In your opinion what should the lead-acid industry be concentrating on to secure a future in the battery market?

The lead industry has to think more about innovation. Companies should nurture teams that focus on seeking out customers' emerging needs. Companies, in my view, have never placed enough emphasis on understanding their major customers' challenges, then engaging in strategic discussions. I once worked with a company, a market leader for many years, that suddenly found its position challenged. When asked how this had happened, they conceded that they hadn't explored what their customers were considering for future needs. Their competitors, with a new technology, soon overtook their position. It's important to know what customers are thinking and what their challenges are.

Finally, how do you see the global battery market developing over the next 10 years?

There is no doubt that the battery industry is in a period of profound change. The industry is growing dramatically and we are now talking about a global sector with valuation of $300 billion or more. But this growth represents enormous challenges as well as opportunities for the industry. The high growth will come from higher energy density batteries, not necessarily lithium but other chemistries.

There are currently initiatives all across the world to find new battery types with lower cost materials that can be easily recycled. There are

going to be enormous challenges for producers to choose a strategic position. As we all know the electric vehicle (EV) market is going to be the biggest sector, and here battery producers will align with automotive partnerships.

Choosing the right partnership will be crucial as battery manufacturers will be dependent on the success of each automotive brand. In the automotive sector, the critical demands of standards such as TS16949 will also improve batteries' performance.

At the moment, the global industry is in an embryonic stage as it tries to capture market positions and partnerships. The major players are gearing for major capacity and this will also cause some issues further up the line. China, the dominant producer of lithium, already has a capacity glut due to the slow-down of its adoption of EVs. Similar things will happen in other areas.

A further issue is that the world is now moving away from globalisation. The implications for the world and specifically the battery industry are profound. The new battery world is one of power electronics as much as batteries. These are businesses that are rebuilding new industries. If we look into regions such as northern Europe, we see lots of new start-up companies developing innovations. These companies are the future and many will be bought up by larger corporations who want to acquire their innovation. These start-up companies are made up of engineers and technicians who are emerging from universities and other industries and see the opportunity to create new customer value propositions. They have an energy and creativity which larger companies often stifle.

An issue that concerns me is that senior managers often get locked into a kind of 'management floor' type thinking. Senior managers can easily get removed from market awareness and its customers. This really struck me when I was promoted out of my battery group role into a senior manager in BTR.

The division I was part of had monthly sales that could read several hundred million. You spend time as a senior manager looking at graphs and spreadsheets with these huge figures and can easily forget where the business comes from. Consolidated sales numbers are made up of thousands of transactions and each of those is a customer need being fulfilled.

As a manager I have spent my life in front of customers and service people. All the while learning from and listening to them. Not only about the products I may have been selling, but also what they think of competitors and market trends. As a guiding principle, senior managers must make time to listen closely their customers, to determine their needs. This is vital for long-term survival.