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The impact of the new 36 V lead–acid battery systems on lead consumption

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Abstract

The production of vehicles utilizing 36 V battery systems has begun with the introduction of the Toyota Crown. Other vehicles with 36 V batteries are in the near horizon. These vehicles may contain single or dual battery systems. These vehicles will most likely contain valve-regulated lead–acid (VRLA) batteries. The battery systems developed to date utilize significantly more lead than conventional 12 V batteries.

This paper will evaluate the different proposed 36 V battery systems and estimate the lead requirements for each of the competing systems. It will also project the penetration of and resultant increased lead usage of these new batteries into the future.

Keywords: Lead–acid batteries; Lead consumption; 36 V Batteries; Replacement batteries; VRLA batteries; Automobile batteries

1. Introduction

The 36 V battery system was first introduced in the Toyota Crown in the autumn of 2001. The Toyota Crown is one example of a multitude of possible new vehicles which will employ the 36 V battery system. The needs for the 36 V systems have been publicized by many authors over the past several years. The major incentive for the change is to provide more power for improved fuel economy (particularly with larger vehicles), enhanced accessories for driver enjoyment, and improved overall efficiency of the vehicle.

Gott [1] has suggested that improved alternator efficiency, electromagnetic valve operation, electric power steering, and an electric water pump will improve fuel efficiency by over 5%. Stop–start systems can produce fuel savings of 5–10% depending on driving style. Consumer creature comforts such as heated windshields, heated and cooled seats, rapid warm or cool cabins, and a variety of electronic enhancements such as phones, navigation systems, and improved speaker systems are more likely to accelerate the movement to 36 V systems than fuel economy alone. Safety enhancements such as drive-by-wire, electric power steering, and active dynamics vehicle control systems, electric braking systems will push vehicle manufacturers to the more powerful 36 V systems.

The 36 V systems present a huge opportunity for the lead–acid battery and lead industries. The 36 V batteries will be larger and contain more lead than conventional starter batteries. The batteries are more likely to be VRLA batteries which can be placed in any area of the vehicle. In larger vehicles and in higher power applications, much larger batteries will be required. The batteries must also have monitoring and control systems to determine state-of-charge, state-of-health, and aging characteristics as well as improved reliability. This paper attempts to evaluate the increased lead usage brought about by the introduction of the more powerful 36 V batteries.

2. Growth of vehicle market

Based on presentations by Amistadi [2], Kubis [3], and Park [4], the original equipment vehicle market is expected to grow at a rate of about 1.6% per year. Improved economic conditions in eastern Europe, the CIS countries, China, and India will lead to the ownership of many more vehicles over the next 20 years. Increased immigration into the US and Europe will also increase vehicle ownership in these areas. Based on the best estimates, the new vehicle production was about 53 million vehicles in 2000. The vehicle production is expected to increase to 79 million vehicles by 2020 as shown in Fig. 1. Despite the current worldwide economic downturn, new vehicles sales have remained high in the US and Europe. The growth in the vehicle population will increase

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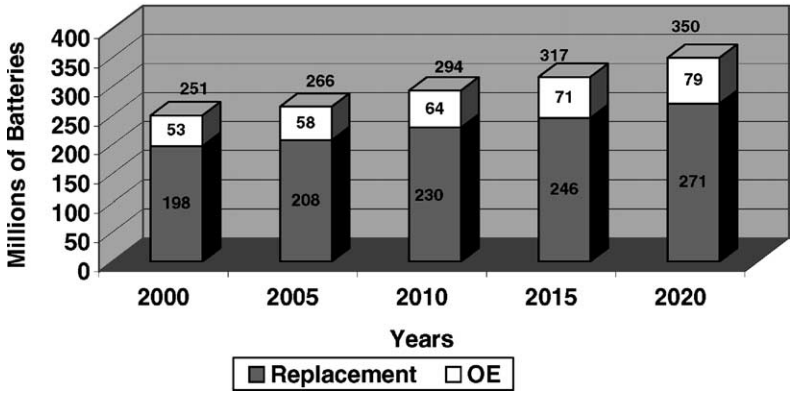

Fig. 1. Projected worldwide OE and replacement batteries.

lead usage in original equipment and replacement batteries throughout the period.

The increase in lead usage is expected to come from the higher lead content of the 36 V systems. These systems are expected to be introduced by about 2005, to gain substantial volume by 2010, and to have nearly complete conversion by 2020. The expected conversion rate to the 36 V system for new vehicles has been estimated by Gott [1] and is shown in Table 1. The conversion in the developed countries such as Japan, North America, and Europe will take place by 2020, but a significant number of vehicles in China, CIS countries, and India may still utilize 12 V systems at that time.

Table 1
The 42 V penetration (%)

	Year			
	2005	2010	2015	2020
European cars				
Small	4.5	29	64.5	100
Medium	1.5	25	62.5	100
Large	4.6	37	68.5	100
Total	2.9	28.3	64.15	100
Japanese cars				
Small	0	2.2	51.1	100
Medium	0.5	27	63.5	100
Large	4.6	77	88.5	100
Total	0.9	25.6	62.8	100
North American cars				
Small	0	25	62.5	100
Medium	0	20	60	100
Large	5	100	100	100
Total	0	28	64	100
North American light trucks				
Large vans	5	50	75	100
Minivans	0	20	60	100
Pick ups	5	50	75	100
SUVs	2	50	75	100
Total	3	45	72.5	100

3. The 36 V battery systems

The 36 V battery system does not always utilize a single battery or battery system. The initial 36 V system introduced in the Toyota Crown utilizes a 12 V battery for vehicle starting and lighting and a 36 V battery for other power requirements. Such a system is relatively simple and requires only a dual tap from the alternator instead of dc/dc converters as suggested by Keim [5]. It is also the system of choice for higher voltage hybrid battery systems such as that employed on the Honda Insight. The dual battery system uses a cranking battery as starter and a deeper discharge battery for the parasitic vehicle loads which cycle the battery. Such a system is relatively inexpensive and may be expected to be the first 36 V system as well as dual 12/12 V systems.

The second system is the 36 V system using a single larger battery. This battery would serve all the functions of the current 12 V system, but would offer more power. Many larger luxury cars currently use large 12 V batteries of up to 130 Ah which is 1.5 kW. These vehicles may use the dual system or a more powerful 36 V system of similar power capabilities. Larger vans, SUVs, and light trucks may require even more power.

The 36 V system with launch assist aids in fuel economy and bridges the gap between a mere SLI battery and one with hybrid battery capability. These batteries are expected to have capacities of at least 1 kW, but also to have power capabilities to provide up to 10 kW as required for launch assist.

The final 36 V system would be the mild hybrid system which utilizes regenerative braking to enhance energy recovery. These batteries are expected to be very large up to 2 kW with 10 kW launch assist and regenerative braking and may find competition with other battery chemistries.

In this analysis, no true hybrid systems using lead–acid batteries are considered. Such a system may be outside the capabilities of 36 V systems and require higher voltages unless very large lead–acid batteries are utilized.

Table 2
Details of proposed 36 V batteries

Battery	Energy (kW)	Weight (kg)	Volume (l)	Capacity *C*/3 (Ah)	Lead content (kg)[a]
Japan storage	0.75	27	9	20	16.2
Yuasa	0.75	24	9	20	14.4
Furakawa	0.65	24	9	18	14.4
Hoppecke/JCI	0.85	28	12	24	16.8
Exide (10 kW) power opt	0.80	25	13	22	18.0
Exide (15 kW) cycle opt	1.3	48	22	35	29.0
East penn	2.4	81	26	65	48.6
Anderman	1.0	37	–	28	22.5
Anderman	2.0	68	–	55	40.8

[a] 60% of battery weight is lead.

4. Details of 36 V battery systems

Several battery manufacturers have announced 36 V batteries for various uses. These are shown in Table 2 along with some estimated battery weights, dimensions, and lead contents from Ohara et al. [6], Furukawa [7], Knauer and Hauck [8], Anderman [9], Trinidad [10], Nakayama [11], and Kuper and Nann [12].

5. Lead content of 36 V batteries

Worldwide SLI batteries in 2000 utilized 2.42 million - tonnes of lead to produce 251 million batteries. Thus, the typical 12 V SLI battery (original equipment and replacement) used about 9.6 kg of lead.

The initial dual voltage (12/36 V battery systems) in the Toyota Crown utilizes a Japan Storage Battery Company 36 V battery containing about 16.2 kg of lead and 12 V starter battery with 9.6 kg of lead. This system utilizes a lead content of 25.8 kg for the whole system. This battery has a capacity of 20 Ah in addition to that of the starter battery.

The 36 V systems of the other Japanese battery companies which contain 14.4 kg of lead in combination with a 12 V battery with 9.6 kg of lead would utilize a lead content of 24.0 kg. The JCI Hoppecke battery contains higher capacity of 24 Ah and a higher lead content of 16.8 kg.

As more power is required it is expected that the battery capacity would increase substantially to accommodate the energy requirements particularly in large cars, SUVs, and vans. Power requirements of 1.5–2 kW for future battery systems suggested by Anderman [10] could contain 22–40 kg of lead, particularly when stop–start, launch assist, and other battery discharge regimes are required.

Initially large vehicles, trucks, and vans would require two batteries (12/36 V) or much larger batteries. These early dual 12/36 V or even larger single batteries are expected to become the 36 V systems for intermediate and small cars as the power requirements increase to near or over 1 kW after 2010. The typical 12 V battery of today has about 0.6 kW. Replacement with a 36 V battery for small vehicles is not expected to be smaller than the 20 Ah (0.75 kW) 36 V battery and may be larger. Intermediate vehicles would utilize a 1–1.2 kW, 36 V battery.

6. Assumptions

1. Projected growth of OE and replacement batteries at 1.8% per year.
2. Increase in 36 V OE registrations from Gott [1] presentation, February 2002, Advanced Automobile Battery Conference.
3. Life of 36 V batteries estimated at 4 years to determine replacement battery volumes.
4. Estimated battery lead content of 12 V batteries is 9.6 kg per battery and 60% of battery weight.
5. Estimated battery lead content of 36 V batteries:

Small cars	16.4 kg	0.85 kW
Medium cars	24.1 kg	1.1 kW
Large cars	25.9 kg	1.2 kW
Vans and SUVs	33.2 kg	1.6 kW

6. A 24.3 kg of lead is used as an average for lead consumed by all 36 V vehicles.

7. North America

7.1. North American battery market

Fig. 2 depicts the development of the battery market in North America for the period 2000–2020. The new vehicles are expected to increase from 17 million in 2000 vehicles to 24 million vehicles by 2020. Replacement batteries increase from 69 to 82 million despite an increased life from 3.5 to 4 years. If the batteries for these vehicles along with the replacement batteries were all 12 V, the total number of 12 V batteries would increase from 68 million in 2000 to 106 million by 2020. Using the data from the Gott [1] for 36 V battery market, the projected original equipment 36 V batteries increase to 8 million in 2010, 16 million by 2015, and 24 million or the entire new vehicle market by 2020 as seen in Fig. 3.

Table 3 describes the projected battery and lead requirements through 2020. Despite significant production of 36 V batteries, the 12 V battery replacement market peaks at 2010 but still maintains a high level of 54 million batteries by 2020. The 36 V replacement market finally exceeds the original equipment batteries by about 2018. As seen from Fig. 1, the major use of 36 V batteries in 2010 is in large vehicles and large cars. It is only in the last 5 years of the study where smaller cars fully utilize 36 V batteries. Replacement batteries in this study are primarily for larger vehicles.

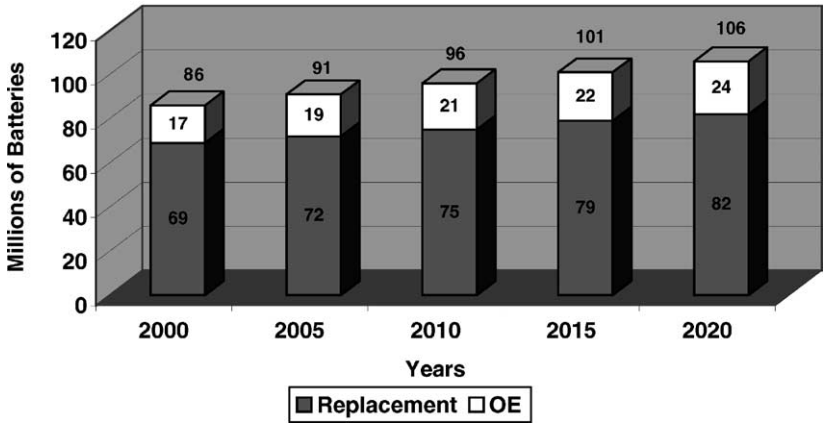

Fig. 2. Projected North American OE and replacement batteries.

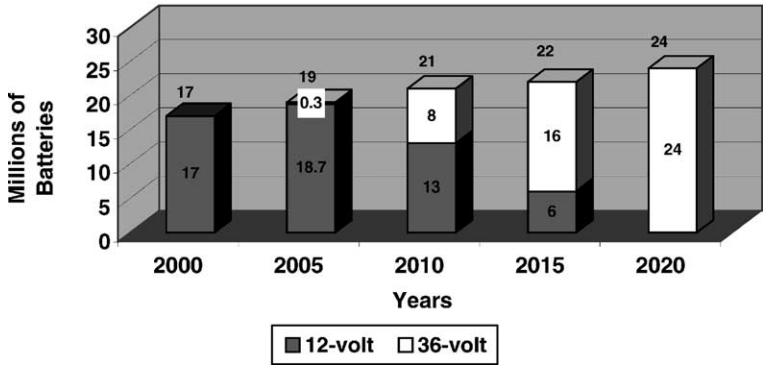

Fig. 3. Projected North American OE batteries.

Table 3
Development of 36 V battery market penetration and resultant lead usage in North America

	Year				
	2000	2005	2010	2015	2020
Millions of batteries					
12 V OE vehicles	17	19	21	22	24
12 V Replacement batteries	69	72	75	79	82
Total 12 V	86	91	96	101	106
With 36 V					
Projected 12 V OE	17	19	13	6	0
Projected 12 V replacement	69	72	73	66	53
Total 12 V	86	91	76	72	53
Projected 36 V OE batteries	0	0.3	8	16	24
Projected 36 V replacement	0	0	2	13	29
Total 36 V	0	0.3	10	29	53
Thousands of tonnes					
Lead usage 12 V	825	875	825	690	510
Lead usage 36 V	0	10	240	705	1280
Total lead usage	825	885	1065	1395	1790
Lead usage without 36 V	825	875	920	970	1020
Increased lead usage with 36 V	0	10	145	425	770

7.2. Lead usage in North America

Because of the growth of the new vehicle population and the total vehicle population, the production of automobile batteries increases significantly from 86 million in 2000 to 106 million in 2020 despite a life increase from 3.5 to 4.0 years. The increase in the number of batteries would have increased the lead usage in automobile and light truck batteries from 825,000 tonnes in 2000 to over 1 million tonnes by 2020 assuming all 12 V batteries.

The predicted lead usage in 12 V batteries peaks at about 875,000 tonnes and decreases to about 510,000 tonnes by 2020. The lead usage in 36 V systems dramatically increases from about 10,000 tonnes in 2005 to about 1.3 million tonnes by 2020. Fig. 4 shows the increased battery market adds about 195,000 tonnes of lead if all the batteries were 12 V, but the introduction of the 36 V batteries adds an additional 770,000 tonnes. The total increase in the North American lead market for automobile batteries more than doubles, from 825,000 to almost 1.8 million tonnes.

Table 4 shows how dramatically the 36 V batteries affect the lead market. OE usage increases from 10,000 tonnes in 2005 to 585,000 tonnes in 2020. The 36 V replacement battery market begins in 2009, but by 2020 exceeds the

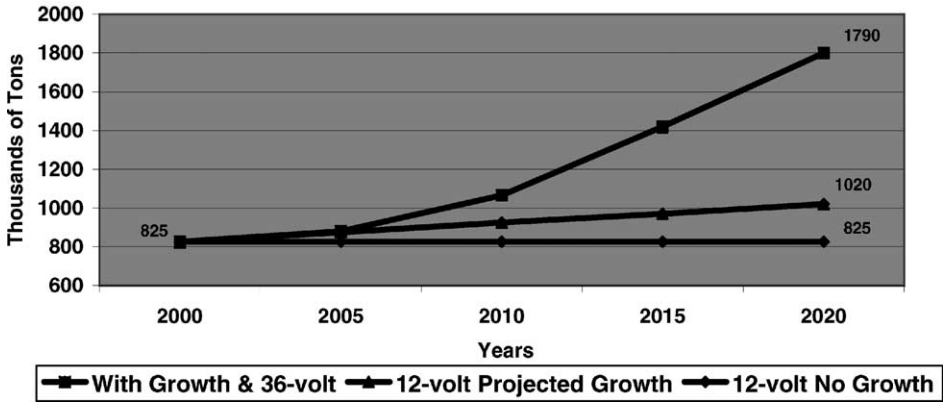

Fig. 4. Projected North American lead usage.

Table 4
Projection of North American 36 V OE and replacement batteries and lead usage

Year	Millions of batteries			Thousands of tonnes			
	36 V Original equipment	36 V Replacement	36 V Total	Lead usage			Increase in lead consumption over 12 V batteries
				OE	Replacement	Total	
2005	0.3			10	0	10	5
2006	1.6			40	0	40	25
2007	3.2			80	0	80	50
2008	4.8			115	0	115	70
2009	6.4	0.3	6.7	155	10	165	100
2010	8.0	1.6	9.6	195	40	235	140
2011	9.6	3.2	12.8	235	80	315	190
2012	11.2	4.8	16.0	270	115	385	235
2013	12.8	6.7	19.5	310	165	475	285
2014	14.4	9.6	24.0	350	235	585	350
2015	16.0	12.8	28.8	390	315	705	425
2016	17.6	15.0	33.6	425	365	790	490
2017	19.2	19.2	38.4	465	465	930	565
2018	20.8	22.4	43.2	505	545	1050	635
2019	22.4	25.6	48.0	545	625	1170	705
2020	24.0	28.8	52.8	585	700	1280	770

OE market with a lead requirement of 700,000 tonnes. The cumulative lead consumption in the 15-year period for 36 V batteries over 12 V batteries increases by over 5 million tonnes.

8. Europe

8.1. European battery market

Fig. 5 shows the projected growth of original equipment and replacement batteries in Europe during the time period 2000–2020. The increased vehicle population comes from eastern Europe and migrations into Europe.

The market for new vehicles is expected to increase from 19 million in 2000 to 23 million by 2020 with a significant increase in the replacement battery business. The total battery market increases from 64 million in 2000 to 85 million in 2020. Following the Gott [1] projections, the introduction of 36 V batteries is slower in Europe than in North America, but by 2020 all the new vehicles have been converted to 36 V systems as seen in Table 5. Similar to North America the 12 V replacement market peaks after 2010 but still remains significant in 2020 as the 12 V vehicle population remains high. Total 36 V batteries exceed 12 V batteries by 2018.

8.2. Lead usage in Europe

The lead required for the increase in batteries from 64 to 85 million would be about 200,000 tonnes had the batteries remained 12 V. The 12 V lead usage increases from 615,000 tonnes in 2002 to a peak of 670,000 tonnes before falling to 345,000 tonnes in 2000. The drop is more than compensated for by the increased lead usage from 615,000 to 1.54 million tonnes in 2020. The lead usage due

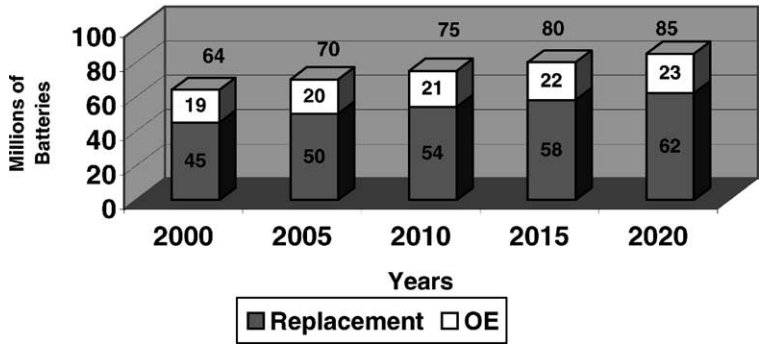

Fig. 5. Projected European OE and replacement batteries.

Table 5
Development of 36 V battery market penetration and resultant lead usage in Europe

	Year				
	2000	2005	2010	2015	2020
Millions of batteries					
12 V OE vehicles	19	20	21	22	23
12 V Replacement batteries	45	50	54	58	62
Total 12 V	64	70	75	80	85
With 36 V					
Projected 12 V OE	19	20	15	7	0
Projected 12 V replacement	45	50	53	48	36
Total 12 V	64	70	68	56	36
Projected 36 V OE batteries	0	0.4	6	15	23
Projected 36 V replacement	0	0	1	10	26
Total 36 V	0	0.4	7	25	49
Thousands of tonnes					
Lead usage 12 V	615	670	650	530	345
Lead usage 36 V	0	10	170	610	1195
Total lead usage	615	680	820	1140	1540
Lead usage without 36 V	615	670	720	770	815
Increased lead usage with 36 V	0	10	100	370	725

to both, the expansion of the battery market (200 tonnes) and the introduction of the 36 V batteries (725 tonnes), increases lead consumption by almost 2.5 times during the period.

The increase in European lead consumption for both original equipment and replacement batteries can be seen in Fig. 6. The dramatic effect of the 36 V batteries is seen in Fig. 6 and Table 6. By the end of the period (2020) yearly lead consumption for 36 V over that which would have been required for 12 V batteries has increased from nothing prior to 2005 to 725,000 tonnes per year in 2020. The cumulative additional lead consumption over the period over the 12 V system is 4.4 million tonnes.

9. Worldwide

9.1. Worldwide battery market

The expansion of lead–acid batteries in new vehicles worldwide is expected to increase dramatically by 2020 as seen in Fig. 1. From about 53 million in 2000, the new vehicle annual production is expected to reach 79 million by 2020. The large increases are expected in the CIS countries, China, India, South America, and Africa where higher increases and improved infrastructure permit more vehicles. There is a similar increase in replacement battery production. Europe and North America, however, still dominate vehicle production although the worldwide percentage from these areas drops from 68% in 2000 to 58% in 2020.

The move to 36 V OE production will not be complete in some countries and about 4% of new vehicles will still be

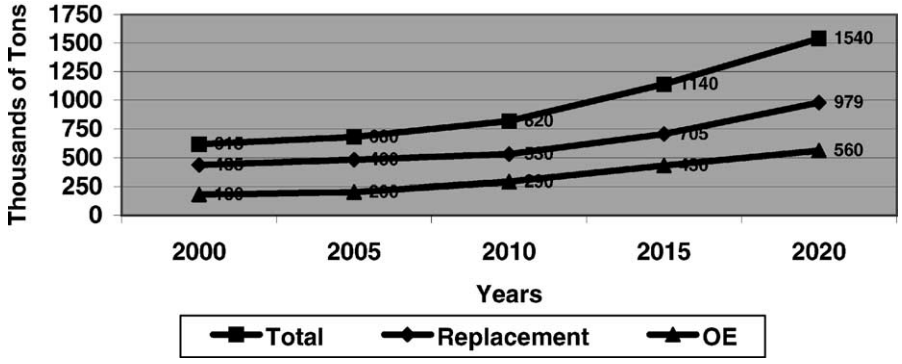

Fig. 6. Projected European lead usage for replacement and original equipment batteries.

Table 6
Projection of European 36 V OE and replacement batteries and lead usage

Year	Millions of batteries			Thousands of tonnes			
	36 V Original equipment	36 V Replacement	36 V Total	Lead usage			Increase in lead consumption over 12 V batteries
				OE	Replacement	Total	
2005	0.4		0.4	10		10	5
2006	1.0		1.0	25		25	15
2007	2.3		2.3	55		55	35
2008	3.5		3.5	85		85	50
2009	4.7	0.4	5.1	115	10	125	75
2010	6.0	1.0	7.0	145	25	170	100
2011	7.8	2.3	10.1	190	55	245	150
2012	9.6	3.5	13.1	235	85	320	190
2013	11.4	5.1	16.5	275	125	400	240
2014	13.2	7.0	20.2	320	170	490	295
2015	15.0	10.1	25.1	365	245	610	370
2016	16.6	13.1	29.7	400	320	720	435
2017	18.2	16.1	34.3	440	390	830	525
2018	19.8	19.2	39.0	480	465	945	550
2019	21.4	22.8	44.2	520	555	1075	650
2020	23.0	26.2	49.2	560	635	1195	725

produced with 12 V systems. These vehicles may have dual 12 V systems, but no increased lead consumption has been taken into account (Table 7).

9.2. Lead consumption worldwide

Fig. 7 shows that the growth of the battery replacement and OE market by 2000 would increase lead demand from 2.42 million tonnes in 2000 to an estimated 3.36 million - tonnes in 2020 without the influence of the 36 V systems. With the 36 V systems there is dramatic increase in lead usage to 5.6 million tonnes in 2020, which is an increase of 2.2 million tonnes over that required for the 12 V batteries. The increase in worldwide lead usage becomes dramatic after 2010 due to the influence of the 36 V battery.

Table 8 shows that worldwide the lead usage in 2020 for 36 V batteries is almost 3.7 million tonnes. It also shows that the cumulative higher lead production (since inception of the 36 V in 2005) has been 13.5 million tonnes for the 36 V batteries compared to that of the 12 V systems.

10. Lead supply

Worldwide an additional 2.2 million tonnes of new lead will be required to satisfy the added requirements for the 36 V over that of the 12 V batteries. This new lead supply may come from some new mined supply, but the majority of the lead may come from a decline in some of the traditional uses for lead which is not recycled such as glass, ceramics, ammunition, pigments, etc. With a current lead supply of about 6 million tonnes and battery usage of about 3.2 million tonnes, there should be adequate lead available for the new batteries. In addition, some of the traditionally

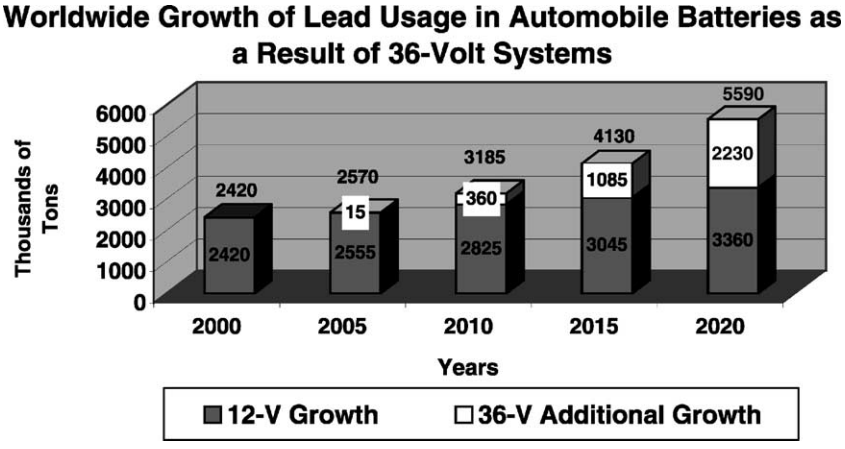

Fig. 7. Projected worldwide lead usage.

Table 7
Development of 36 V battery market penetration and resultant lead usage worldwide

	Year				
	2000	2005	2010	2015	2020
Millions of batteries					
12 V OE vehicles	53	58	64	71	79
12 V Replacement batteries	198	208	230	242	271
Total 12 V	251	266	294	313	350
With 36 V					
Projected 12 V OE	53	57	44	30	3
Projected 12 V replacement	194	208	225	209	195
Total 12 V	252	265	269	239	198
Projected 36 V OE batteries	0	1	20	41	76
Projected 36 V replacement	0	0	5	33	76
Total 36 V	0	1	25	74	152
Thousands of tonnes					
Lead usage 12 V	2420	2545	2590	2295	1900
Lead usage 36 V	0	25	605	1800	3690
Total lead usage	2420	2570	3185	4095	5590
Lead usage without 36 V	2420	2555	2825	3005	3360
Increased lead usage with 36 V	0	15	360	1090	2230

non-recycled uses for lead such as CRT screens may be replaced by newer non-lead bearing glass technologies or the glass screens will be recycled.

11. Recycling of 36 V batteries

The construction of the 36 V batteries envisioned for future 42 V power net applications are not expected to be significantly different from the prototype 36 V batteries seen in Table 2. They are expected to be VRLA batteries using lead-calcium-tin or pure lead grid technology and AGM separators. Some of the hazardous materials used in wet SLI batteries today such as arsenic will be eliminated from the 36 V VRLA batteries.

Table 9
Capacity required to recycle 12 and 36 V batteries in North America[a]

Year	12 V	36 V	Total	Increase
2000	660	0	660	0
2005	690	0	690	30
2010	720	30	750	90
2015	760	190	950	290
2020	785	425	1210	550

[a] Thousands of tonnes.

The increase in batteries and lead content is expected to increase the requirements for recycling capacity for the new 36 V batteries. In North America, as seen in Table 9, the growth of the lead content of the 12 V batteries available for recycling should increase from 660,000 tonnes in 2000 to 785,000 tonnes in 2020. The scrapped 36 V batteries would add an additional 425,000 tonnes of lead available for recycling by 2020. The total assumed required growth in recycling capacity in North America is expected to be 550,000 tonnes per year.

This is currently the equivalent of five new 110,000 tonnes recycling plants. The increase is expected to be accommodated by increased capacity at present recycling plants and possibly the construction of one or two new plants.

Europe shows a similar increased requirement for recycling capacity as North America. This is seen in Table 10. Since the recycling plants in Europe are smaller, one would expect the increase to be accommodated by expansion of existing facilities.

Worldwide, the required recycling capacity will increase by 700,000 tonnes over that of Europe and North America by 2020 as seen in Table 11. Since the battery growth is

Table 8
Projected worldwide 36 V OE and replacement batteries and lead usage

Year	36 V			Lead usage			Increase in lead consumption over 12 V
	OE	Replacement	Total	OE	Replacement	Total	
2005	1.0			25			15
2006	4.8			115			70
2007	8.6			210			125
2008	12.4			300			180
2009	16.2	1.0	17.2	395	25	420	250
2010	20.0	4.8	24.8	485	115	600	365
2011	24.2	8.6	32.8	590	210	800	480
2012	28.4	12.4	40.8	690	300	990	600
2013	32.6	17.2	49.8	790	415	1205	730
2014	36.8	24.8	61.6	895	605	1500	910
2015	41.0	32.8	73.8	995	800	1795	1085
2016	47.2	40.8	88.0	1145	970	2115	1295
2017	54.0	48.8	102.8	1310	1185	2495	1510
2018	61.0	56.8	117.8	1480	1380	2860	1730
2019	68.0	65.2	133.2	1650	1585	3235	1960
2020	76.0	75.6	152.0	1845	1845	3690	2230

Table 10
Capacity required to recycle 12 and 36 V batteries in Europe[a]

Year	12 V	36 V	Total	Increase
2000	430	0	430	0
2005	480	0	480	50
2010	520	15	535	105
2015	555	150	705	275
2020	595	380	975	545

[a] Thousands of tonnes.

Table 11
Capacity required to recycle 12 and 36 V batteries worldwide[a]

Year	12 V	36 V	Total	Increase
2000	1910	0	1910	0
2005	1995	0	1995	85
2010	2210	70	2280	370
2015	2325	485	2810	900
2020	2600	1115	3715	1805

[a] Thousands of tonnes.

expected to take place in many parts of the world without significant battery recycling capacity, new battery collection and recycling systems will need to be implemented to handle the expected increase in scrapped batteries in an environmentally safe manner.

12. Summary

A small but continuous increase in new vehicle production is predicted to raise annual production to 79 million by 2020. This will produce a significant increase in lead usage by raising consumption from 2.42 million tonnes to 3.36 million tonnes.

The 36 V system introduced in significant numbers after 2005 will dramatically increase lead consumption by more than doubling the 2000 requirement to 5.5 million tonnes.

The advent of the 36 V battery system is the most significant event for the lead industry as well as the lead–acid battery industry. The lead industry has the opportunity to experience a dramatic increase in lead consumption and at the same time battery companies have the opportunity to increase the return on their product. The major problem facing the industry is the development of reliable, long life batteries to fill this need.

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