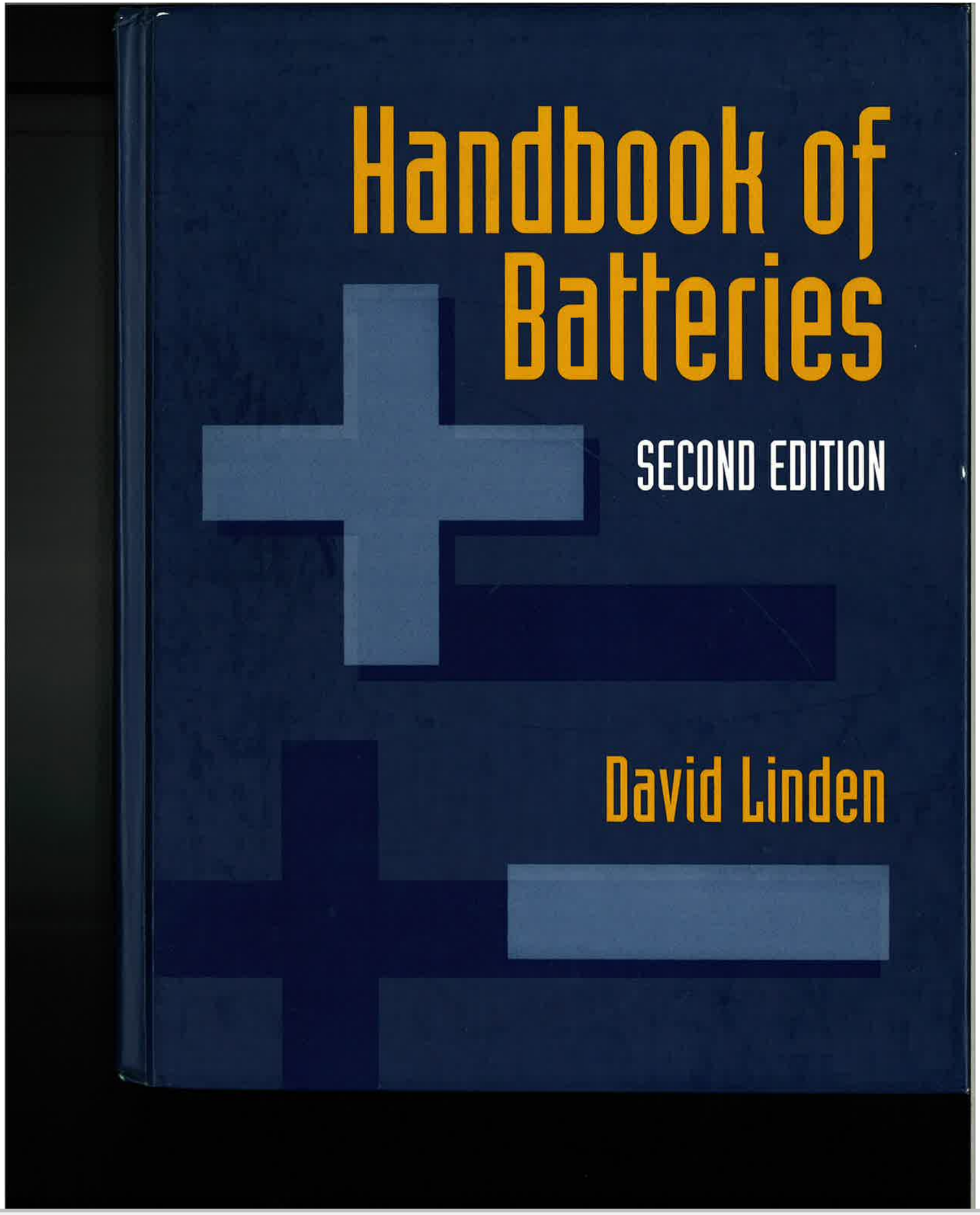

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David Linden Editor in Chief

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TABLE 23.3 Characteristics of the Major Secondary Battery Systems

	Lead-acid				Nickel-cadmium			Nickel-iron (conventional)	Nickel-zinc
Common name	SLI	Traction	Stationary	Portable	Vented pocket plate	Vented sintered plate	Sealed		
Chemistry:									
Anode	Pb	Pb	Pb	Pb	Cd	Cd	Cd	Fe	Zn
Cathode	PbO_2	PbO_2	PbO_2	PbO_2	NiOOH	NiOOH	NiOOH	NiOOH	NiOOH
Electrolyte	H_2SO_4 (aqueous solution)	H_2SO_4 (aqueous solution)	H_2SO_4 (aqueous solution)	H_2SO_4 (aqueous solution)	KOH (aqueous solution)	KOH (aqueous solution)	KOH (aqueous solution)	KOH (aqueous solution)	KOH (aqueous solution)
Cell voltage (typical), V:									
Nominal	2.0	2.0	2.0	2.0	1.2	1.2	1.2	1.2	1.6
Open circuit	2.1	2.1	2.1	2.1	1.29	1.29	1.29	1.37	1.73
Operating	2.0–1.8	2.0–1.8	2.0–1.8	2.0–1.8	1.25–1.00	1.25–1.00	1.25–1.00	1.25–1.05	1.6–1.4
End	1.75 (lower operating and end voltage during cranking operation)	1.75	1.75 (except when on float service)	1.75 (when cycled)	1.0	1.0	1.0	1.0	1.2
Operating temperature, °C	−40 to 55	−20 to 40	−10 to 40[c]	−40 to 60	−20 to 45	−40 to 50	−40 to 45	−10 to 45	−20 to 60
Energy density (at 20°C):									
Wh/kg	35	25	10–20	30	20	37	30–35	27	60
Wh/L	70	80	50–70	90	40	90	80–105	55	120
Discharge profile (relative)	Flat	Flat	Flat	Flat	Flat	Very flat	Very flat	Moderately flat	Flat
Power density	High	Moderately high	Moderately high	High	High	High	Moderate to high	Moderate to low	High
Self-discharge rate (at 20°C), % loss per month[b]	20–30 (Sb-Pb) 2–3 (maintenance-free)	4–6	—	4–8	5	10	15–20	20–40	10
Calendar life, years	3–6	6	18–25	2–8	8–25	3–10	2–5	8–25	—
Cycle life, cycles[c]	200–700	1500	—	250–500	500–2000	500–2000	300–700	2000–4000	50–200
Advantages	Low cost, ready availability, good high-rate, high- and low-temperature operation (good cranking service), good float service, new maintenance-free designs	Lowest cost of competitive systems (also see SLI)	Designed for "float" service, lowest cost of competitive systems (also see SLI)	Maintenance-free; long life on float service; low- and high-temperature performance; no "memory" effect; operates in any position	Very rugged, can withstand physical and electrical abuse; good charge retention, storage and cycle life lowest cost of alkaline batteries	Rugged; excellent storage; good specific energy and high-rate and low-temperature performance	Sealed, no maintenance; good low-temperature and high-rate performance; long life cycle; operates in any position	Very rugged, can withstand physical and electrical abuse; long life (cycling or stand)	High energy density; relatively low cost; good low-temperature performance
Limitations	Relatively low cycle life; limited energy density; poor charge retention and storability; hydrogen evolution	Low energy density; less rugged than competitive systems; hydrogen evolution	Hydrogen evolution	Cannot be stored in discharged condition; lower cycle life than sealed nickel-cadmium; difficult to manufacture in very small sizes	Low energy density	High cost; "memory" effect; thermal runaway	Sealed lead-acid battery better at high temperature and float service, "memory" effect	Low power and energy density; high self-discharge; hydrogen evolution; high cost	Poor cycle life
Major cell types available	Prismatic cells: 30–200 Ah at 20-h rate	Based on positive plate design: 45–200 Ah per positive plate	Based on positive plate design: 5–400 Ah per positive plate	Sealed cylindrical cells: 2.5–25 Ah; prismatic cells: 0.9–35 Ah	Prismatic cells: 5–1300 Ah	Prismatic cells: 10–100 Ah	Button cells to 0.5 Ah; cylindrical cells to 10 Ah	New designs in development for EV and mobile traction	Not commercially available

[a] Based on $C/LiCoO_2$ lithium-ion cell (see Chap. 36) (characteristics vary with battery system and design).
[b] Self-discharge rate usually decreases with increasing storage time.
[c] Dependent on depth of discharge.
[d] Low-rate Zn/AgO cell.

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