

Handbook of Batteries

SECOND EDITION

David Linden

Electrical Engineering

*An update of the definitive guide to
all aspects of battery design and selection*

Handbook of Batteries

SECOND EDITION

Here is the one and only reference to offer you detailed data and information on the characteristics, properties, performance, and applications of all types of electric batteries.

Written by a staff of leading experts in battery technology, this essential working tool covers batteries for everything from small portable consumer items to electric vehicles and military and industrial equipment.

The new edition of the *Handbook of Batteries* shows you how to:

- Determine the performance characteristics of batteries under all conditions of use
- Establish the conditions and proper operating procedures to achieve optimum use of each battery system
- Select the most suitable battery for a given application

The Second Edition now features the latest data, tables, and figures covering the vast improvements in battery performance in recent years—and also explores new battery technologies, including lithium and rechargeable batteries.

Whether you're an engineer, technician, or product designer, the updated edition of this one-of-a-kind sourcebook enables you to take advantage of the many new advances in the fast-changing field of battery technology.

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HANDBOOK OF BATTERIES

David Linden Editor in Chief

Second Edition

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SECONDARY BATTERIES

TABLE 23.3 Characteristics of the Major Secondary Battery Systems

Common name	Lead-acid				Nickel-cadmium			Nickel-iron (conventional)	Nickel-zinc
	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 ₂ SO ₄ (aqueous solution)	H ₂ SO ₄ (aqueous solution)	H ₂ SO ₄ (aqueous solution)	H ₂ SO 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	1.75	1.75	1.75	1.0	1.0	1.0	1.0	1.2
	(lower operating and end voltage during cranking operation)		(except when on float service)		(when cycled)				
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)	4-6	—	4-8	5	10	15-20	20-40	10
	2-3 (maintenance-free)								
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/LiCoO₂ 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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