Tubular Gel

Valve Regulated Lead Acid Batteries

Technical Manual

HBL™

Introduction

HBL, a leading manufacturer of specialized batteries introduces 'TUBULAR GEL VALVE REGULATED LEAD ACID' batteries through in-house Research and Development. Tubular Gel technology based on gas recombination principle, meets the international quality standards and is proven by rigorous laboratory and field tests and are the ideal choice for applications in Solar, Telecommunications and Railways. This product has been manufactured under the controls established by a quality/environment management system that meets the requirements of ISO 9001 and ISO 14001.

Requirements of SPV Applications

Charge input from solar arrays is insufficient to keep the batteries fully charged. During sun-less days, batteries are discharged but not charged. These conditions result in battery operating in Partial State of Charge (PSOC), Cycling and Deep cycling. Also, solar systems are installed in open atmosphere exposing the batteries to extreme temperatures . Other lead acid batteries fail in such conditions due to sulphation, stratification, corrosion and active material shedding. Moreover, remote solar installations make water top-up difficult and expensive.

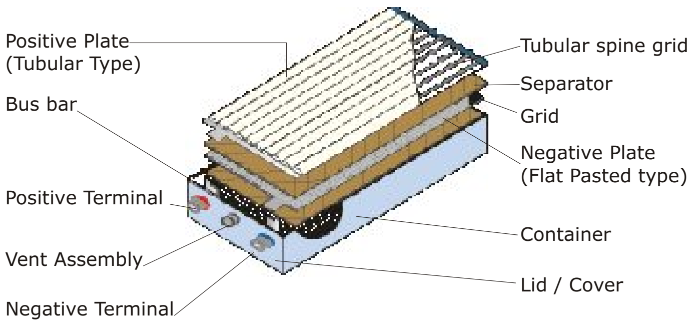
Requirements of Telecom Applications

Pressure to reduce costs of telecom equipment is forcing the batteries out of air-conditioned rooms to roadside shelters exposing them to higher temperatures thereby increasing the concern on reliability of batteries. Net result is the need for a heavy duty, robust, deep cycling battery which is less sensitive to high temperatures.

To meet such rigors of usage, HBL introduces a maintenance free (no water top-up) "Tubular Gel VRLA battery" with unbeatable combination of Tubular plate and Gelled electrolyte that is a perfect fit for Solar, Telecom, Railway and any such demanding applications.

Tubular Gel Technology

Design & Construction



- **Positive Plate**

  Tubular Plate with lead-calcium-tin alloy spine grid and woven polyester gauntlet.
- **Negative Plate**

  Flat pasted plate with lead-calcium alloy grid and long life expander material.
- **Separator**

  Micro porous synthetic separator.
- **Electrolyte**

  Sulphuric acid, immobilized as thixotropic gel.
- **Container & Cover**

  Polypropylene, Flame retardant is optional.
- **Valve**

  Self-resealing, Pressure-regulating and Explosion-proof with flame arrestor.
- **Terminals**

  Epoxy sealed terminals with threaded lead-plated copper alloy inserts.
- **Steel trays**

  Acid resistant, epoxy powder coated, stackable boxes for easy installation.
- **Connectors**

  Lead plated copper connectors.

IEC 60896-2 Certified

UL Recognized component

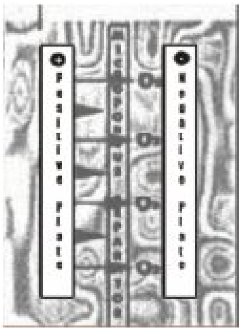
Gas Recombination in Tubular Gel Battery

In conventional lead acid cells, water is lost from the cell due to venting of hydrogen, oxygen and droplets of sulphuric acid entrained in the gas stream thus there is a need of regular battery checks and periodic water top-up operations to maintain the electrolyte at the required level. The sealed, valve regulated lead acid battery design, eliminates these problems through continuous recombination of the oxygen during charging. In a tubular Gel VRLA battery the electrolyte is in the form of thixotropic gel, which is not spillable. Microcracks are developed in gel which facilitates oxygen transfer from positive plate to negative plate to form water at high degree of efficiency.

Basic gas recombination principle in Gel battery is as follows:

At the end of discharge or during overcharging, Oxygen gas is released at the positive plates

$$H_2O \longrightarrow 2\,H^+ + ½\,O_2 + 2\,e^-$$



The oxygen diffuses across the gelled electrolyte and microporus separator to the negative plate.

The oxygen reacts chemically with the Spongy lead of the active material to form Lead oxide.

$$Pb + 1/2\,O_2 \longrightarrow PbO$$

The sulphuric acid (Electrolyte) reacts with the Lead oxide, giving Lead sulphate and water.

$$PbO + H_2SO_4 \longrightarrow PbSO_4 + H_2O$$

Part of the spongy lead in negative plate is thus chemically discharged to lead sulphate and water consumed at the positive plate is regenerated.

On recharge the Lead sulphate, which is formed at the negative plate, is transformed electro-chemically into lead, to return sulphuric acid.

$$PbSO_4 + 2H^+ + 2\,e^- \longrightarrow Pb + H_2SO_4$$

As long as the battery remains fully charged, this equilibrium is maintained. Here no water top-up is required.

The charge and discharge reaction of the lead acid battery can be expressed by the following equation :

$$Pb + PbO_2 + 2H_2SO_4 \rightleftharpoons 2PbSO_4 + 2\,H_20$$

The above reaction is reversible.

Performance

Parameter	2 Volt Single Cell	12 Volts Monobloc
Design Float Life at 25°C	20 years	16 years
Cycle Life at 25°C @ 80% DOD	1800 Cycles	1200 Cycles
Cycle Life at 25°C @ 20% DOD	5200 Cycles	3500 Cycles
Self Discharge	<2% per month at 25°C	
AH Efficiency	>95%	
WH Efficiency	>85%	
Operating Temperature	-20º C to +55º C	

Features

- Tubular positive plates
- Gelled electrolyte
- Filled and charged
- Valve regulated
- Antimony - free alloy
- High pressure die-cast spine grids
- Excellent thermal management
- Ready to install
- Versatile in mounting

Benefits

- Proven cycling and deep cycling capabilities
- No stratification and no failure due to PSOC
- Ready to use, easier to install
- No water top-up during service life
- Long shelf life because of very low self-discharge
- Rate of grid corrosion is very low
- Enhancement in life
- 100% capacity on first discharge
- Can be mounted both in horizontal and vertical orientation

'TGI' Batteries Conforms to the Specifications of

- IEC / EN 60896-21 & 22
- IEC 61427
- BS 6290 part IV
- IEEE 1188, 1189 Specification
- EUROBAT Guide 1999 - Classified as "Long Life"

Applications

Telecommunications

Wireless

Transmission

Switching

SPV

Rural Electrification

Street Lighting

Home Lighting

Telecommunications

Offshore Platforms

Hybrid Power Systems

Navigational Aids

Railways

Railway Signaling

Telecommunications

SCADA Systems

EPABX Systems

Solar PV Systems

***Suitable for any other applications which involve cycling, deep discharge & high temperature operations**

Charging Specification

Solar Photo Voltaic Applications

On/Off Type

- Over Voltage Disconnect: 2.370±0.005 V/ Cell at 25°C
- Array Reconnection Voltage: 2.250±0.005 V/ Cell at 25°C
- Low Voltage Disconnect: 1.850±0.005 V/ Cell at 25°C
- Load Reconnect Voltage: 2.080±0.005 V/ Cell at 25°C

Pulse Width modulation (CV Controller) Type

- Regulation Voltage: 2.350±0.005 V/ Cell at 25°C
- Low Voltage Disconnect: 1.850±0.005 V/ Cell at 25°C
- Load Reconnection Voltage: 2.080±0.005 V/ Cell at 25°C

Telecom and Other Applications

Float & Semi-Cyclic Applications

- Float voltage: 2.250±0.005 V/cell at 25°C
- Boost voltage: 2.300±0.005 V/cell at 25°C
- Current limit: 0.1 C10 Amps (Min.) to 0.2 C10 Amps (Max.)
- Ripple: Should be less than 3% RMS
- Float to boost change over: Battery charging current is >5% of C_{10} Amps
- Boost to Float change over: Battery charging current is <3% of C_{10} Amps

Cyclic Applications

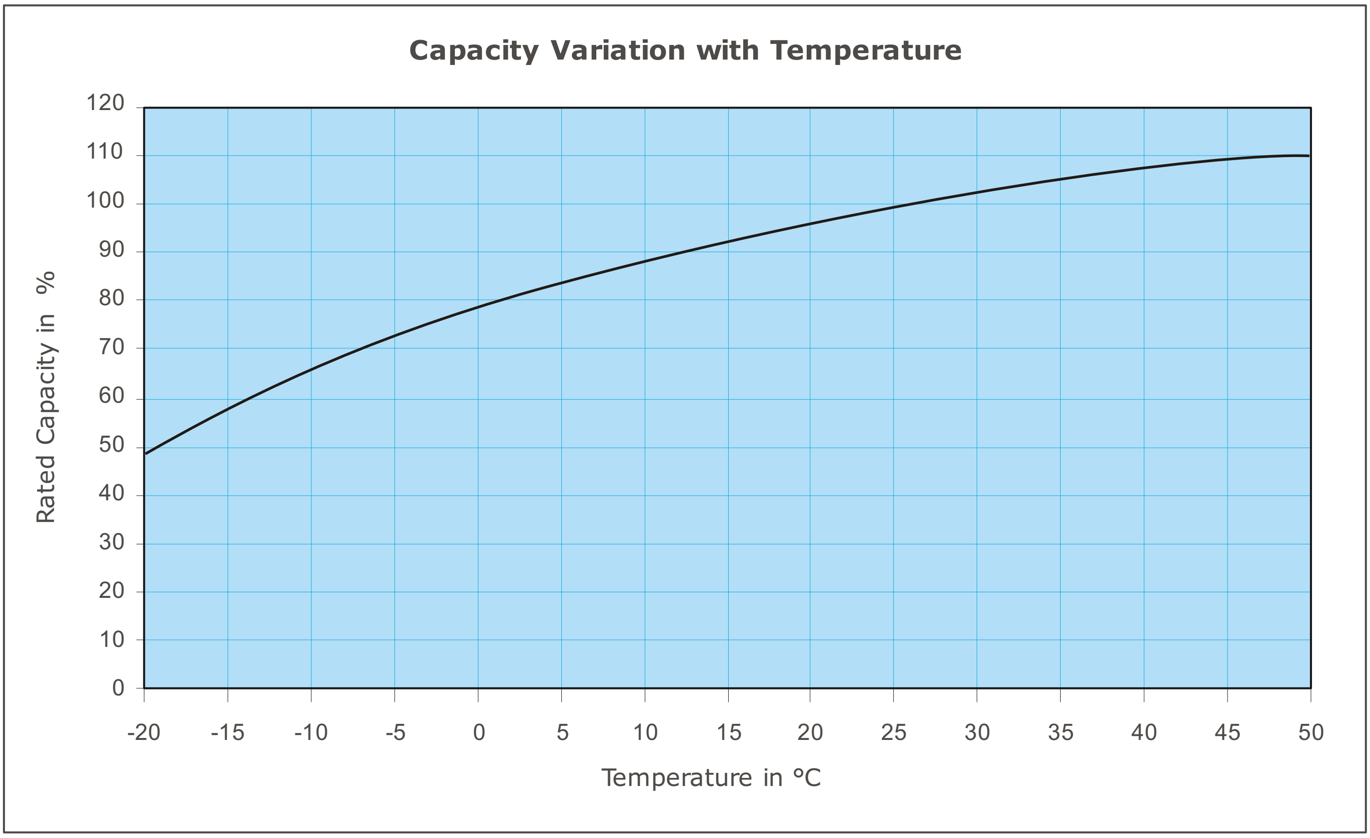
- Float voltage: 2.250±0.005 V/cell at 25°C
- Boost voltage: 2.350±0.005 V/cell at 25°C
- Current limit: 0.1 C10 Amps (Min.) to 0.2 C10 Amps (Max.)
- Ripple: Should be less than 3% RMS
- Float to boost change over: Battery charging current is >5% of C10 Amps
- Boost to Float change over: Battery charging current is <3% of C10 Amps

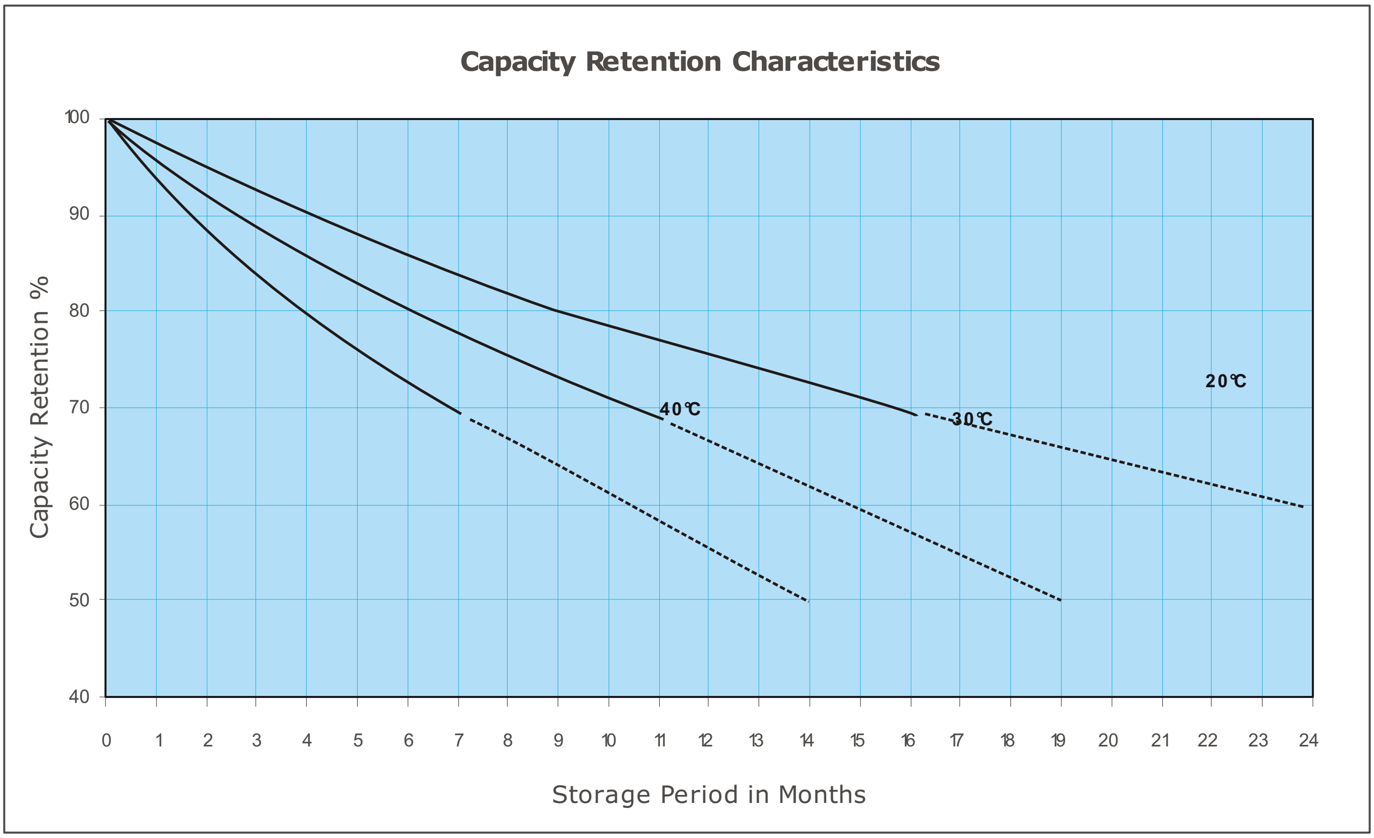
Product Specifications

Model	Monobloc/ Module Voltage	Nominal Capacity (Ah) at C_{10}	Monobloc/Module Dimensions & Weights			
			Length (±10mm)	Width (±10mm)	Height (±10mm)	Weight (Approx)
12 Volt Monoblocs						
12 TGI 40	12	40	410	174	221	27
12 TGI 60	12	60	410	174	221	31
12 TGI 80	12	80	526	221	226	46
12 TGI 100	12	100	526	221	226	50
2 Volt Cells						
2 TGI 120	16	120	762	445	185	93
2 TGI 160	16	160	770	445	220	111
2 TGI 200	16	200	770	445	263	130
2 TGI 240	16	240	770	445	311	167
2 TGI 280	16	280	770	445	338	184
2 TGI 300	8	300	770	445	211	104
2 TGI 320	8	320	770	445	211	106
2 TGI 360	8	360	770	445	252	132
2 TGI 400	8	400	770	445	252	138
2 TGI 440	8	440	770	445	281	153
2 TGI 480	8	480	770	445	281	165
2 TGI 500	8	500	770	445	281	167
2 TGI 625	6	625	590	705	240	159
2 TGI 700	6	700	590	705	240	171
2 TGI 775	6	775	590	705	273	184
2 TGI 850	6	850	590	705	273	201
2 TGI 1000	6	1000	594	705	324	240
2 TGI 1250	6	1250	600	705	369	282

* Nominal Capacity is at a discharge rate of 10 Hrs to an end cell voltage of 1.80 V at 25º C

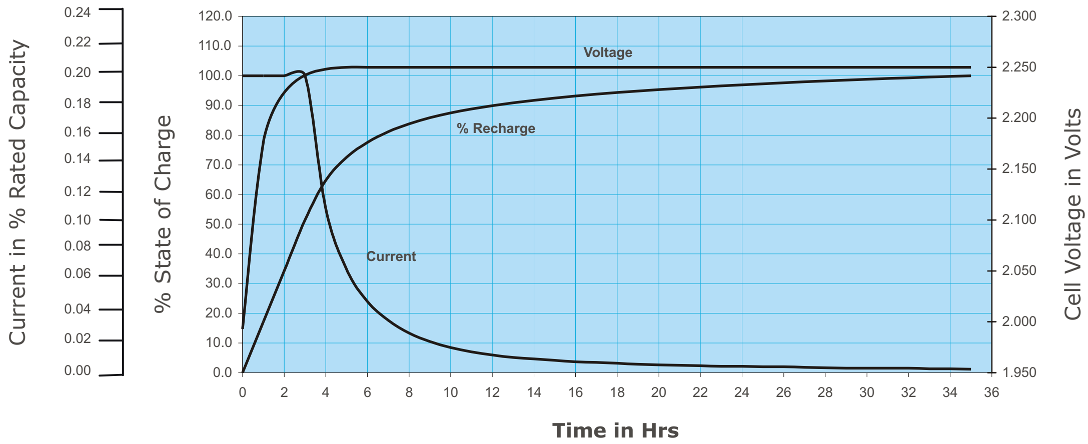
Battery Characteristics



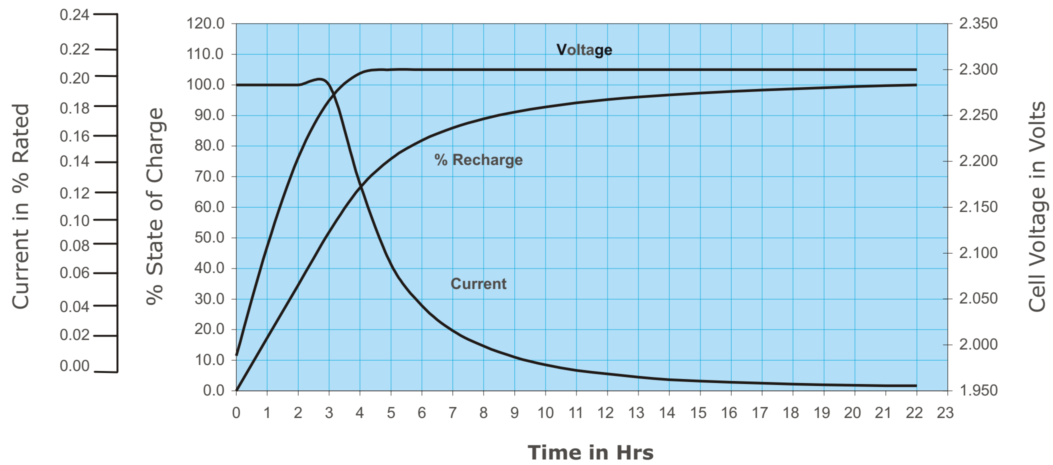


Battery Characteristics

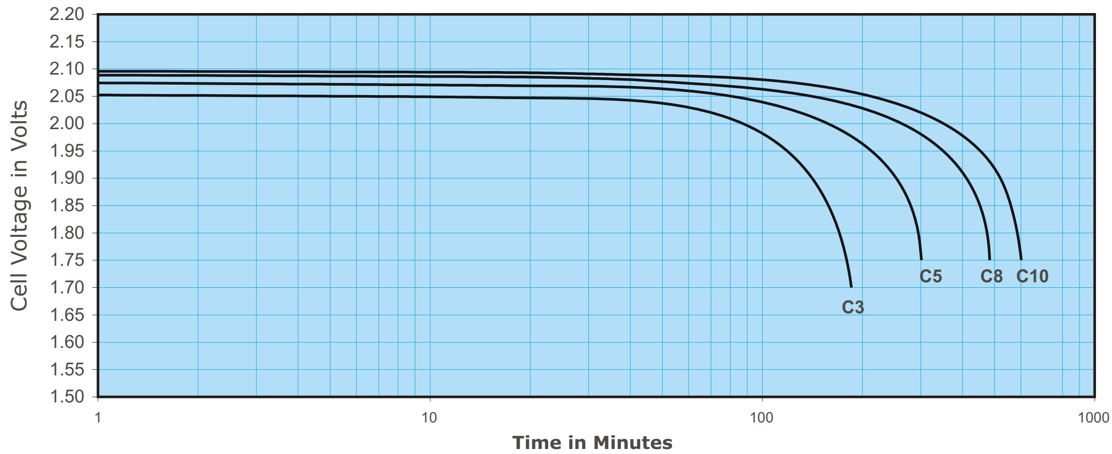
Charging Characteristics - Constant Voltage Charging at 2.250 V/Cell, Current Limited to 0.2 C10



Charging Characteristics - Constant Voltage Charging at 2.300 V/Cell, Current Limited to 0.2 C10



Performance Curves at Different Rates of Discharge



Discharge Characteristics in Amps to 1.75 V/Cell (10.5 V/Bloc)*

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours										
		1	1.5	2	3	4	5	6	7	8	9	10
12 TGI 40	40	22.9	17.4	14.2	10.6	8.4	6.9	6.0	5.3	4.8	4.4	4.1
12 TGI 60	60	34.3	26.1	21.3	16.0	12.6	10.3	9.0	8.0	7.2	6.6	6.2
12 TGI 80	80	45.7	34.8	28.4	21.3	16.8	13.8	11.9	10.7	9.7	8.8	8.2
12 TGI 100	100	57.1	43.5	35.5	26.6	21.0	17.2	14.9	13.3	12.1	11.0	10.3
2 TGI 120	120	68.6	52.2	42.6	31.9	25.2	20.7	17.9	16.0	14.5	13.2	12.4
2 TGI 160	160	91.4	69.6	56.7	42.6	33.6	27.6	23.9	21.3	19.3	17.6	16.5
2 TGI 200	200	114.3	87.0	70.9	53.2	42.0	34.5	29.9	26.7	24.2	22.0	20.6
2 TGI 240	240	137.1	104.3	85.1	63.8	50.4	41.4	35.8	32.0	29.0	26.4	24.7
2 TGI 280	280	160.0	121.7	99.3	74.5	58.8	48.3	41.8	37.3	33.8	30.8	28.8
2 TGI 300	300	171.4	130.4	106.4	79.8	63.0	51.7	44.8	40.0	36.2	33.0	30.9
2 TGI 320	320	182.9	139.1	113.5	85.1	67.2	55.2	47.8	42.7	38.6	35.2	33.0
2 TGI 360	360	205.7	156.5	127.7	95.7	75.6	62.1	53.7	48.0	43.5	39.6	37.1
2 TGI 400	400	228.6	173.9	141.8	106.4	84.0	69.0	59.7	53.3	48.3	44.0	41.2
2 TGI 440	440	251.4	191.3	156.0	117.0	92.4	75.9	65.7	58.7	53.1	48.4	45.3
2 TGI 480	480	274.3	208.7	170.2	127.7	100.8	82.8	71.6	64.0	58.0	52.8	49.4
2 TGI 500	500	285.7	217.4	177.3	133.0	105.0	86.2	74.6	66.7	60.4	55.0	51.5
2 TGI 625	625	357.1	271.7	221.6	166.2	131.3	107.8	93.3	83.3	75.5	68.8	64.4
2 TGI 700	700	400.0	304.3	248.2	186.2	147.1	120.7	104.5	93.3	84.5	77.0	72.1
2 TGI 775	775	442.9	337.0	274.8	206.1	162.8	133.6	115.7	103.3	93.6	85.3	79.8
2 TGI 850	850	485.7	369.6	301.4	226.1	178.6	146.6	126.9	113.3	102.7	93.5	87.5
2 TGI 1000	1000	571.4	434.8	354.6	266.0	210.1	172.4	149.3	133.3	120.8	110.0	103.0
2 TGI 1250	1250	714.3	543.5	443.3	332.4	262.6	215.5	186.6	166.7	151.0	137.5	128.7

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours					
		20	24	48	72	100	120
12 TGI 40	40	2.46	2.13	1.17	0.81	0.63	0.55
12 TGI 60	60	3.69	3.19	1.75	1.21	0.94	0.82
12 TGI 80	80	4.92	4.25	2.34	1.61	1.25	1.10
12 TGI 100	100	6.15	5.32	2.92	2.01	1.57	1.37
2 TGI 120	120	7.38	6.38	3.50	2.42	1.88	1.65
2 TGI 160	160	9.84	8.51	4.67	3.22	2.51	2.20
2 TGI 200	200	12.30	10.63	5.84	4.03	3.13	2.75
2 TGI 240	240	14.76	12.76	7.01	4.83	3.76	3.30
2 TGI 280	280	17.22	14.89	8.18	5.64	4.39	3.85
2 TGI 300	300	18.45	15.95	8.76	6.04	4.70	4.12
2 TGI 320	320	19.68	17.01	9.34	6.44	5.01	4.40
2 TGI 360	360	22.14	19.14	10.51	7.25	5.64	4.95
2 TGI 400	400	24.60	21.27	11.68	8.05	6.27	5.50
2 TGI 440	440	27.06	23.39	12.85	8.86	6.89	6.05
2 TGI 480	480	29.52	25.52	14.01	9.67	7.52	6.60
2 TGI 500	500	30.75	26.58	14.60	10.07	7.83	6.87
2 TGI 625	625	38.44	33.23	18.25	12.59	9.79	8.59
2 TGI 700	700	43.05	37.21	20.44	14.10	10.97	9.62
2 TGI 775	775	47.66	41.20	22.63	15.61	12.14	10.66
2 TGI 850	850	52.28	45.19	24.82	17.12	13.32	11.69
2 TGI 1000	1000	61.50	53.16	29.20	20.14	15.67	13.75
2 TGI 1250	1250	76.88	66.45	36.50	25.17	19.58	17.19

*Performance of a fully charged cell at 25°C

Discharge Characteristics in Amps to 1.80 V/Cell (10.8 V/Bloc)*

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours										
		1	1.5	2	3	4	5	6	7	8	9	10
12 TGI 40	40	22.5	17.1	13.7	10.2	8.2	6.7	5.8	5.2	4.6	4.2	4.0
12 TGI 60	60	33.7	25.6	20.6	15.3	12.3	10.0	8.7	7.8	7.0	6.3	6.0
12 TGI 80	80	44.9	34.2	27.5	20.5	16.5	13.3	11.6	10.3	9.3	8.4	8.0
12 TGI 100	100	56.2	42.7	34.4	25.6	20.6	16.7	14.5	12.9	11.6	10.5	10.0
2 TGI 120	120	67.4	51.3	41.2	30.7	24.7	20.0	17.4	15.5	13.9	12.6	12.0
2 TGI 160	160	89.9	68.4	55.0	40.9	32.9	26.7	23.2	20.7	18.5	16.8	16.0
2 TGI 200	200	112.4	85.5	68.7	51.2	41.2	33.3	29.0	25.8	23.2	21.0	20.0
2 TGI 240	240	134.8	102.6	82.5	61.4	49.4	40.0	34.8	31.0	27.8	25.2	24.0
2 TGI 280	280	157.3	119.7	96.2	71.6	57.6	46.7	40.6	36.2	32.4	29.4	28.0
2 TGI 300	300	168.5	128.2	103.1	76.7	61.7	50.0	43.5	38.8	34.8	31.5	30.0
2 TGI 320	320	179.8	136.8	110.0	81.8	65.8	53.3	46.4	41.3	37.1	33.6	32.0
2 TGI 360	360	202.2	153.8	123.7	92.1	74.1	60.0	52.2	46.5	41.7	37.8	36.0
2 TGI 400	400	224.7	170.9	137.5	102.3	82.3	66.7	58.0	51.7	46.3	42.0	40.0
2 TGI 440	440	247.2	188.0	151.2	112.5	90.5	73.3	63.8	56.8	51.0	46.2	44.0
2 TGI 480	480	269.7	205.1	164.9	122.8	98.8	80.0	69.6	62.0	55.6	50.4	48.0
2 TGI 500	500	280.9	213.7	171.8	127.9	102.9	83.3	72.5	64.6	57.9	52.5	50.0
2 TGI 625	625	351.1	267.1	214.8	159.8	128.6	104.2	90.6	80.7	72.4	65.7	62.5
2 TGI 700	700	393.3	299.1	240.5	179.0	144.0	116.7	101.4	90.4	81.1	73.5	70.0
2 TGI 775	775	435.4	331.2	266.3	198.2	159.5	129.2	112.3	100.1	89.8	81.4	77.5
2 TGI 850	850	477.5	363.2	292.1	217.4	174.9	141.7	123.2	109.8	98.5	89.3	85.0
2 TGI 1000	1000	561.8	427.4	343.6	255.8	205.8	166.7	144.9	129.2	115.9	105.0	100.0
2 TGI 1250	1250	702.2	534.2	429.6	319.7	257.2	208.3	181.2	161.5	144.8	131.3	125.0

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours					
		20	24	48	72	100	120
12 TGI 40	40	2.40	2.07	1.11	0.76	0.60	0.53
12 TGI 60	60	3.60	3.10	1.66	1.14	0.90	0.80
12 TGI 80	80	4.80	4.13	2.22	1.52	1.20	1.06
12 TGI 100	100	6.00	5.17	2.77	1.90	1.50	1.33
2 TGI 120	120	7.20	6.20	3.32	2.28	1.80	1.59
2 TGI 160	160	9.60	8.27	4.43	3.04	2.40	2.12
2 TGI 200	200	12.00	10.34	5.54	3.79	3.00	2.65
2 TGI 240	240	14.40	12.40	6.65	4.55	3.60	3.18
2 TGI 280	280	16.80	14.47	7.75	5.31	4.20	3.71
2 TGI 300	300	18.00	15.50	8.31	5.69	4.50	3.98
2 TGI 320	320	19.20	16.54	8.86	6.07	4.80	4.24
2 TGI 360	360	21.60	18.60	9.97	6.83	5.40	4.77
2 TGI 400	400	24.00	20.67	11.08	7.59	6.00	5.30
2 TGI 440	440	26.39	22.74	12.18	8.35	6.60	5.83
2 TGI 480	480	28.79	24.81	13.29	9.11	7.20	6.36
2 TGI 500	500	29.99	25.84	13.85	9.49	7.50	6.63
2 TGI 625	625	37.49	32.30	17.31	11.86	9.37	8.28
2 TGI 700	700	41.99	36.18	19.39	13.28	10.50	9.28
2 TGI 775	775	46.49	40.05	21.46	14.70	11.62	10.27
2 TGI 850	850	50.99	43.93	23.54	16.13	12.75	11.26
2 TGI 1000	1000	59.99	51.68	27.69	18.97	15.00	13.25
2 TGI 1250	1250	74.99	64.60	34.62	23.71	18.75	16.56

*Performance of a fully charged cell at 25°C

Discharge Characteristics in Amps to 1.85 V/Cell (11.1 V/Bloc)*

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours										
		1	1.5	2	3	4	5	6	7	8	9	10
12 TGI 40	40	21.3	16.1	13.0	9.8	7.8	6.3	5.5	4.9	4.4	4.0	3.8
12 TGI 60	60	31.9	24.2	19.5	14.6	11.7	9.5	8.2	7.3	6.6	6.0	5.6
12 TGI 80	80	42.6	32.3	26.1	19.5	15.7	12.7	10.9	9.7	8.8	8.0	7.5
12 TGI 100	100	53.2	40.3	32.6	24.4	19.6	15.8	13.7	12.2	11.0	10.0	9.4
2 TGI 120	120	63.8	48.4	39.1	29.3	23.5	19.0	16.4	14.6	13.2	12.0	11.3
2 TGI 160	160	85.1	64.5	52.1	39.0	31.3	25.3	21.9	19.5	17.6	16.0	15.1
2 TGI 200	200	106.4	80.6	65.1	48.8	39.1	31.6	27.3	24.3	22.0	20.0	18.8
2 TGI 240	240	127.7	96.8	78.2	58.5	47.0	38.0	32.8	29.2	26.4	24.0	22.6
2 TGI 280	280	148.9	112.9	91.2	68.3	54.8	44.3	38.3	34.1	30.8	28.0	26.4
2 TGI 300	300	159.6	121.0	97.7	73.2	58.7	47.5	41.0	36.5	33.0	30.0	28.2
2 TGI 320	320	170.2	129.0	104.2	78.0	62.6	50.6	43.7	38.9	35.2	32.0	30.1
2 TGI 360	360	191.5	145.2	117.3	87.8	70.5	57.0	49.2	43.8	39.6	36.0	33.9
2 TGI 400	400	212.8	161.3	130.3	97.6	78.3	63.3	54.6	48.7	44.0	40.0	37.7
2 TGI 440	440	234.0	177.4	143.3	107.3	86.1	69.6	60.1	53.5	48.4	44.0	41.4
2 TGI 480	480	255.3	193.5	156.4	117.1	93.9	75.9	65.6	58.4	52.8	48.0	45.2
2 TGI 500	500	266.0	201.6	162.9	122.0	97.8	79.1	68.3	60.8	55.0	50.0	47.1
2 TGI 625	625	332.4	252.0	203.6	152.4	122.3	98.9	85.4	76.0	68.8	62.5	58.9
2 TGI 700	700	372.3	282.3	228.0	170.7	137.0	110.8	95.6	85.2	77.0	70.0	65.9
2 TGI 775	775	412.2	312.5	252.4	189.0	151.7	122.6	105.9	94.3	85.3	77.5	73.0
2 TGI 850	850	452.1	342.7	276.9	207.3	166.3	134.5	116.1	103.4	93.5	85.0	80.0
2 TGI 1000	1000	531.9	403.2	325.7	243.9	195.7	158.2	136.6	121.7	110.0	100.0	94.2
2 TGI 1250	1250	664.9	504.0	407.2	304.9	244.6	197.8	170.8	152.1	137.5	125.0	117.7

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours					
		20	24	48	72	100	120
12 TGI 40	40	2.26	1.98	1.05	0.72	0.56	0.50
12 TGI 60	60	3.39	2.96	1.58	1.08	0.84	0.75
12 TGI 80	80	4.52	3.95	2.10	1.44	1.12	1.00
12 TGI 100	100	5.65	4.94	2.63	1.81	1.40	1.25
2 TGI 120	120	6.78	5.93	3.15	2.17	1.68	1.50
2 TGI 160	160	9.04	7.91	4.20	2.89	2.24	2.00
2 TGI 200	200	11.30	9.88	5.25	3.61	2.80	2.50
2 TGI 240	240	13.56	11.86	6.31	4.33	3.36	3.00
2 TGI 280	280	15.82	13.83	7.36	5.06	3.92	3.50
2 TGI 300	300	16.95	14.82	7.88	5.42	4.20	3.75
2 TGI 320	320	18.08	15.81	8.41	5.78	4.48	4.00
2 TGI 360	360	20.34	17.79	9.46	6.50	5.04	4.50
2 TGI 400	400	22.60	19.76	10.51	7.22	5.60	5.00
2 TGI 440	440	24.86	21.74	11.56	7.95	6.16	5.50
2 TGI 480	480	27.12	23.72	12.61	8.67	6.72	6.00
2 TGI 500	500	28.25	24.70	13.14	9.03	7.00	6.25
2 TGI 625	625	35.31	30.88	16.42	11.29	8.75	7.81
2 TGI 700	700	39.55	34.58	18.39	12.64	9.80	8.75
2 TGI 775	775	43.79	38.29	20.36	13.99	10.85	9.69
2 TGI 850	850	48.02	42.00	22.33	15.35	11.90	10.63
2 TGI 1000	1000	56.50	49.41	26.27	18.06	14.00	12.50
2 TGI 1250	1250	70.62	61.76	32.84	22.57	17.50	15.63

*Performance of a fully charged cell at 25°C

Discharge Characteristics in Amps to 1.90 V/Cell (11.4 V/Bloc)*

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours										
		1	1.5	2	3	4	5	6	7	8	9	10
12 TGI 40	40	19.6	15.0	12.1	9.0	7.3	5.8	5.1	4.5	4.1	3.7	3.5
12 TGI 60	60	29.4	22.5	18.1	13.5	10.9	8.7	7.7	6.8	6.1	5.5	5.2
12 TGI 80	80	39.2	30.0	24.2	18.1	14.6	11.7	10.2	9.1	8.1	7.3	6.9
12 TGI 100	100	49.0	37.5	30.2	22.6	18.2	14.6	12.8	11.3	10.2	9.2	8.7
2 TGI 120	120	58.8	44.9	36.3	27.1	21.9	17.5	15.3	13.6	12.2	11.0	10.4
2 TGI 160	160	78.4	59.9	48.3	36.1	29.2	23.3	20.4	18.1	16.3	14.7	13.9
2 TGI 200	200	98.0	74.9	60.4	45.1	36.5	29.2	25.5	22.7	20.3	18.3	17.3
2 TGI 240	240	117.6	89.9	72.5	54.2	43.8	35.0	30.6	27.2	24.4	22.0	20.8
2 TGI 280	280	137.3	104.9	84.6	63.2	51.1	40.8	35.7	31.7	28.5	25.7	24.3
2 TGI 300	300	147.1	112.4	90.6	67.7	54.7	43.7	38.3	34.0	30.5	27.5	26.0
2 TGI 320	320	156.9	119.9	96.7	72.2	58.4	46.6	40.8	36.3	32.5	29.3	27.7
2 TGI 360	360	176.5	134.8	108.8	81.3	65.7	52.5	45.9	40.8	36.6	33.0	31.2
2 TGI 400	400	196.1	149.8	120.8	90.3	73.0	58.3	51.0	45.4	40.7	36.7	34.7
2 TGI 440	440	215.7	164.8	132.9	99.3	80.3	64.1	56.1	49.9	44.7	40.3	38.1
2 TGI 480	480	235.3	179.8	145.0	108.4	87.6	70.0	61.2	54.4	48.8	44.0	41.6
2 TGI 500	500	245.1	187.3	151.1	112.9	91.2	72.9	63.8	56.7	50.8	45.8	43.3
2 TGI 625	625	306.4	234.1	188.8	141.1	114.1	91.1	79.7	70.9	63.5	57.3	54.2
2 TGI 700	700	343.1	262.2	211.5	158.0	127.7	102.0	89.3	79.4	71.1	64.2	60.7
2 TGI 775	775	379.9	290.3	234.1	174.9	141.4	113.0	98.9	87.9	78.8	71.0	67.2
2 TGI 850	850	416.7	318.4	256.8	191.9	155.1	123.9	108.4	96.4	86.4	77.9	73.7
2 TGI 1000	1000	490.2	374.5	302.1	225.7	182.5	145.8	127.6	113.4	101.6	91.7	86.7
2 TGI 1250	1250	612.7	468.2	377.6	282.2	228.1	182.2	159.4	141.7	127.0	114.6	108.3

Model	Nominal Capacity (Ah) at C_{10}	Discharge Time in Hours					
		20	24	48	72	100	120
12 TGI 40	40	2.09	1.79	0.97	0.67	0.53	0.47
12 TGI 60	60	3.14	2.69	1.45	1.01	0.79	0.70
12 TGI 80	80	4.19	3.59	1.94	1.34	1.05	0.93
12 TGI 100	100	5.23	4.48	2.42	1.68	1.32	1.17
2 TGI 120	120	6.28	5.38	2.90	2.02	1.58	1.40
2 TGI 160	160	8.37	7.17	3.87	2.69	2.11	1.87
2 TGI 200	200	10.47	8.97	4.84	3.36	2.63	2.33
2 TGI 240	240	12.56	10.76	5.81	4.03	3.16	2.80
2 TGI 280	280	14.65	12.56	6.77	4.71	3.69	3.27
2 TGI 300	300	15.70	13.45	7.26	5.04	3.95	3.50
2 TGI 320	320	16.75	14.35	7.74	5.38	4.21	3.73
2 TGI 360	360	18.84	16.14	8.71	6.05	4.74	4.20
2 TGI 400	400	20.93	17.94	9.68	6.72	5.27	4.67
2 TGI 440	440	23.02	19.73	10.65	7.39	5.79	5.13
2 TGI 480	480	25.12	21.52	11.61	8.07	6.32	5.60
2 TGI 500	500	26.16	22.42	12.10	8.40	6.58	5.83
2 TGI 625	625	32.71	28.03	15.12	10.50	8.23	7.29
2 TGI 700	700	36.63	31.39	16.94	11.76	9.22	8.17
2 TGI 775	775	40.55	34.75	18.75	13.03	10.20	9.04
2 TGI 850	850	44.48	38.12	20.57	14.29	11.19	9.92
2 TGI 1000	1000	52.33	44.84	24.20	16.81	13.17	11.67
2 TGI 1250	1250	65.41	56.05	30.24	21.01	16.46	14.58

*Performance of a fully charged cell at 25°C

K-Factors

Discharge Time in Hours	End Cell/bloc Voltage			
	1.75 V / Cell (10.5 V / Bloc)	1.80 V / Cell (10.8 V / Bloc)	1.85 V / Cell (11.1 V / Bloc)	1.90 V / Cell (11.4 V / Bloc)
1	1.75	1.78	1.88	2.04
1.5	2.30	2.34	2.48	2.67
2	2.82	2.91	3.07	3.31
3	3.76	3.91	4.10	4.43
4	4.76	4.86	5.11	5.48
5	5.81	6.00	6.33	6.86
6	6.70	6.90	7.32	7.84
7	7.50	7.74	8.22	8.82
8	8.28	8.63	9.09	9.84
9	9.09	9.52	10.00	10.91
10	9.71	10.00	10.62	11.54
20	16.26	16.67	17.70	19.11
24	18.81	19.35	20.24	22.30
48	34.25	36.11	38.06	41.33
72	49.66	52.71	55.38	59.50
100	63.83	66.67	71.43	75.95
120	72.73	75.47	80.00	85.71

Selecting the right battery

The selection of the battery for a certain duty requires some information about the use. Discharge currents, backup time, operating voltage window and temperature are the basic parameters necessary for selecting a right battery. Depending upon the duty cycle and the condition under which the battery is operating, suitable correction factors viz,. K-Factors, Temperature correction factor, and Ageing factors are to be used to determine the best techno economic choice of the battery for any application. A battery-sizing programme developed by HBL can be used to arrive at a suitable battery model.

Correction Factors

K-Factor : This factor is to be considered to estimate the available battery capacity at different discharge rates and end cell voltages. K-Factor is the ratio of rated capacity to the discharge current in amperes that can be supplied by the battery for 't' duration to a given end voltage.

Temperature Correction Factor: This factor is to be considered to take care of the variations in performance of the battery at different temperatures. As the operating temperature increases above 25°C, the electrochemical reaction is enhanced. Thus, the capacity available increases, but the life of the battery reduces. Therefore no derating factor is to be applied to the performance of the battery for sizing when the battery operates at higher temperature. However, electrical capacity at lower temperatures is lesser due to sluggish electro chemical activity. Therefore, temperature-derating factor is to be applied for sizing the battery for low temperature applications. Temperature correction factors are given below.

Ambient Temp in °C	-20	-15	-10	-5	0	5	10	15	20	25
Correction Factor	2.08	1.72	1.49	1.35	1.27	1.19	1.14	1.09	1.04	1.00

Ageing Factor: IEEE Std 485 recommends that, a battery needs to be replaced when its actual capacity drops to 80 % of its rated capacity. To get desired capacity from the battery even at the end of its life, battery shall be oversized by 25 % of the required capacity. Hence a correction factor of 1.25 should be taken as ageing factor.

Design Margin: In general 10% cushion is considered while sizing to accommodate unforeseen operating conditions such as improper maintenance, frequent discharges without proper recharge, ambient temperature lower than the anticipated or a combination of these factors. However this design margin cannot sustain the abusive conditions for longer periods.

Over Load Factor: It is pure reserve capacity that may be installed to take care of any future additional load. In general 10-15% overload factor is considered. However this depends on customer requirement and shall only be considered if specified by the customer.

Depth of Discharge Factor: In cyclic applications, to avoid deep discharging of the battery, depth of discharge shall be limited to a maximum of 80 %. However the depth of discharge can be limited to any value less than 80 % based on customer specification / application.

Types of Load

Common duty cycles imposed on the battery can be classified as (a) Continuous load and (b) Non continuous load. Continuous loads are energized throughout the duty cycle where as Non continuous loads are energized only in portions of the duty cycle.

Continuous loads

Constant current discharge: (Eg. **Telecom**)

Eg.1: Selection of a battery for supplying a load of 15 Amps for 6 hours to an end cell voltage of 1.80V when the system voltage is 48V at an ambient temperature of 25°C.

The information required / given for battery sizing is :

Load current	:	15 Amps
Backup time	:	6 hrs
System voltage	:	48 Volts
End cell voltage	:	1.80 Volts
Temperature	:	25°C

Calculations

Number of cells = System voltage / Nominal Voltage

= 48/2

= 24 cells

Capcity required = Load current X Backup time. Since the battery is designed for 10 hour rate, for 6 hours backup, K-factor need to be applied.

From the K-factor table, for 1.80 ECV and discharge time for 6 hrs, the K-factor is 6.90

Required battery capacity = 15 X 6.90 = 103.5 Ah

Applying Ageing Factor of 1.25, sized battery capacity = 103.5 X 1.25 =129.38 Ah

From tables the nearest higher available capacity, 160Ah is chosen. Thus the battery selected is 24 cells of 2 TGI 160.

Constant current discharge for long duration rates (Eg. Solar photovoltaic)

Eg.2: Selection of a battery for supplying a Load current of 4 Amps for the Autonomy of 5 days.

The system voltage is 48 volts and end cell voltage is 1.85

The information required / given for battery sizing is :

Load current	:	4 Amps
System Voltage	:	48 Volts
Autonomy (back up time)	:	5 days
Average ambient temperature	:	25°C
End Cell Voltage	:	1.85 Volts

Calculations :

No. Of Cells = 48/2 = 24

Total back up time required = 24 hrs X 5 days = 120 hrs

$$\text{Battery capacity required} = \frac{\text{Load current X K factor (for back up time)}}{\text{80\% (maximum allowable depth of discharge)}}$$

K factor for 120 hrs = 80.00

So required battery capacity = 4*80.00/0.8

= 400 Ah

Applying ageing factor of 1.25 = 400*1.25

= 500 Ah

Therefore Ah capacity 500Ah is chosen. Thus the battery selected is 24 cells of 2 TGI 500

Temperature Compensation

Temperature (°C)	2 Volt Single Cell		12 Volts Monobloc	
	Float Voltage / Cell (Volts)	Boost Voltage / Cell (Volts)	Float Voltage / Bloc (Volts)	Boost Voltage / Bloc (Volts)
-10	2.355	2.405	14.130	14.430
0	2.325	2.375	13.950	14.250
10	2.295	2.345	13.770	14.070
20	2.265	2.315	13.590	13.890
25	2.250	2.300	13.500	13.800
30	2.235	2.285	13.410	13.710
35	2.220	2.270	13.320	13.620
40	2.205	2.255	13.230	13.530
45 to 55	2.200	2.250	13.200	13.500

Table A

Float/Boost Voltage for temperatures other than 25°C shall be calculated with the following formula
For 2V Single Cells : $V_T = V_{25} - \{(T-25)X0.003\ V/°C\}$
For 12V Monoblocs : $V_T = V_{25} - \{(T-25)X0.018\ V/°C\}$

Ventilation Requirements

Life of VRLA batteries will be affected by the operating temperature. So for optimum life and considering the safety aspects, battery shall be operated in appropriate environment with proper ventilation. Battery operating room / cabinet dimensions are to be calculated as detailed below:

To reduce hydrogen concentration in battery cabinets

Hydrogen evolution under over charge condition can be calculated as follows:

V = N x I x 0.00045 Cub.Mt (Ref standard: **BS 6133 1995, Annexure A**)

Where,

V = Volume of Hydrogen released from the battery per hr
N = No. of 2V cells in the battery
I = Over charge current in Amperes &
0.00045 is a constant

Formula for estimating the of concentration of Hydrogen gas after 1 hr charging

% Hydrogen = (Hydrogen volume, $V_{Hydrogen}$ / Volume of Air, V_{air}) x 100

Where, Volume of Air = Volume of Cabinet -Volume of Battery

So, to keep the % hydrogen below 1% of the air volume, appropriate dimensions of room/cabinet and air changes/hr should be selected.

Important Instructions

Parameter	Specification	Negative effects if NOT Followed
Float Voltage at 25 °C	2.250 ± 0.005 V Cell / 13.50 ± 0.030 V/ bloc	a) Less than 2.250V/Cell / 13.50 V/bloc: **Gradual reduction in capacity.** b) Equal to 2.300V/Cell / 13.80 V/bloc at 25 ° C: **50 % reduction in life.** c) Equal to 2.350V/Cell / 14.10 V/bloc at 25 ° C: **75 % reduction in life.** d) Greater than 2.350V/Cell / 14.10 V/bloc at 25 ° C: **Maximum failure due to Thermal Runaway.**
Float to boost change over	When battery draws a current $\geq$ **5%** of its rated capacity.	Fails to give required backup due to insufficient charging.
Boost to float change over	When battery draws a current $\leq$ **3%** of its rated capacity.	Reduced life due to overcharge and dry out.
Temperature compensation for float voltage	**+3 mV/°C/ cell / +18 mV/°C/ bloc** for temperatures below 25° C **-3 mV/°C/ cell / –18 mV/° C/ bloc** for temperatures above 25° C	Failure due to undercharge Reduced life due to overcharge. Thermal runaway at higher temperatures.
Hydrogen concentration in the cabinet / room	Should be less than **1 %** of cabinet / room by volume	Possible fire / explosion
Excessive heat around the battery	Battery temperature should not be more than **10 ° C** above the ambient temperature (considering a maximum ambient temperature of **55 ° C)**.	Leads to dry out and subsequently Thermal Runaway.
Battery path current limit on power plant / charger	Shall be between **0.1 C_{10}** to **0.2 C_{10}**	a) More than 0.2 C10: **Leads to dry out.** b) Less than 0.1 C10: **Leads to under charging.**
Ripple in current / voltage	Should be less than **3 %** RMS	Hear generation, Dry out and Thermal Runway.

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