SCHEDULE-29

Standards and Labelling(S&L) program

For

High-Energy Lithium-Ion traction Battery packs and systems

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Schedule 29 **Date: 14th December 2021**

High-Energy Lithium-Ion traction battery packs and systems

1. SCOPE

This schedule specifies energy-labelling requirement for high-energy Lithium-Ion based Battery packs and systems for electrically propelled road vehicles. The schedule covers high-energy lithium-ion battery packs/modules with specific energy up to 350Wh/kg and Cycle life up to 4,000 cycles. For this schedule, the star rating of high-energy Battery pack/module shall be based on specific energy, life cycle and energy efficiency tested in accordance with ISO 12405-4:2018. India specific exceptions to ISO 12405-4:2018 adopted in the present schedule are as per recommendation of the technical committee constituted by Bureau of Energy Efficiency (BEE) for this purpose.

2. Normative references

This schedule shall be read in conjunction with the following standards, for the purpose of star labelling of the packs.

NOTE: For undated references, the current version with all amendments are to be followed. For dated references, the version with all amendments are to be followed.

S. No.	Standard
1	ISO 6469-1, Electrically propelled road vehicles — Safety specifications — Part 1: Rechargeable energy storage system (RESS)
2	ISO 6469-34, Electrically propelled road vehicles — Safety specifications —Part 3: Electrical Safety
3	AIS 048 - Battery Operated Vehicles - Safety Requirements of Traction Batteries
4	IS 16046 (Part 1): 2018/ IEC 62133-1: 2017 - 'Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes — Safety Requirements for Portable Sealed Secondary Cells and for Batteries Made from Them for Use in Portable Applications Part 1 Nickel Systems: 2018/ IEC 62133-1: 2017 - 'Secondary Cells and Batteries Containing Alkaline or Other Non-Acid Electrolytes — Safety Requirements for Portable Sealed Secondary Cells and for Batteries
5	IEC 62660-2:2018 Secondary Lithium-ion Cells for the Propulsion of Electrical Road Vehicles-Part 2: Reliability and Abuse Testing
6	IEC 62660-3:2016 Secondary Lithium-ion Cells for the Propulsion of Electrical Road Vehicles Part 3: – Safety Requirements

3. Terminology

For this schedule, the following definitions shall apply. However, in case of dispute, the definitions given in 'ISO 12405- Part (4): 2018 electrically propelled road vehicles — Test specification for lithium-ion traction battery packs and systems' shall be referred.

3.1. Battery Control Unit (BCU)

BCU is an electronic device that controls, manages, detects or calculates electric and thermal functions of the battery system and provides communication between the battery system and other vehicle controllers.

3.2 Battery pack

Energy storage device that includes cells or cell assemblies normally connected with cell electronics, power supply circuits and overcurrent shut-off device(s), including electrical interconnections, interfaces for external systems.

3.3 Battery system

Energy storage device that includes cells or cell assemblies or battery pack(s) as well as electrical circuits and electronics.

3.4 Capacity:

Total number of ampere hours that can be withdrawn from a fully charged battery pack under specified conditions. The capacity is often expressed in ampere-hours (A·h), where 1 A·h = 3 600 C.

3.5 Cell electronics

Electronic device that collects and possibly monitors thermal and electric data of cells or cell assemblies and contains electronics (including a cell controller) for cell balancing, if necessary.

3.6 Energy density

Amount of stored energy related to the battery pack or system volume. The battery pack or system includes the cooling system, if any, to the point of a reversible attachment of the coolant lines or air ducts, respectively. Energy density is expressed in watt hours per liter (W·h/l).

3.7 Specific Energy

Amount of stored energy related to the battery pack or system mass. The battery pack or system includes the cooling system, if any, to the point of a reversible attachment of the coolant lines or air ducts, respectively. For liquid-cooled systems, the coolant mass inside the battery pack or system is included. Specific energy is expressed in watt hours per kilogram (W·h/kg).

3.8 Energy Round-Trip Efficiency

Ratio of the net d.c. energy delivered by a DUT (battery pack/ system) during a discharge test to the total d.c. energy required to restore the initial SOC by a standard charge. The net d.c. energy is expressed as watt hours (W·h) discharge and the total d.c. energy is expressed as watt hours (W·h) charge.

3.9 High-energy application

Characteristic of device or application, for which the numerical ratio between maximum allowed electric power output and electric energy output at 1 C discharge rate at room temperature for a battery pack or system is typically lower than 10. Typically high-energy battery packs and systems are designed for applications in BEVs. The allowed electric power output is expressed as power in watts (W) and the electric energy output is expressed as energy in watt hours (W·h).

3.10 Maximum working voltage

Highest value of a.c. voltage (r.m.s) or of d.c. voltage which may occur in an electrical system under any normal operating conditions according to the manufacturer's specifications, disregarding transients.

3.11 Rated capacity

Supplier's specification of the total number of Ampere hours (A.h) that can be withdrawn from a fully charged battery pack or system for a specified set of test conditions, such as discharge rate, temperature and discharge cut off voltage.

3.12 Room Temperature (RT)

Room temperature of (27 ± 2) °C.

3.14 Sign of battery Current

Discharge current is specified as positive and the charge current as negative.

3.15 State of charge (SOC)

SOC is the available capacity in a battery pack or system. State of charge is expressed as a percentage of rated capacity.

3.16 Supplier party

The one who provides battery systems and packs. For example, a battery manufacturer.

3.17 Voltage class A:

Classification of an electric component or circuit with a maximum working voltage of ≤ 30 V a.c. or ≤ 60 V d.c., respectively

NOTE For more details, see ISO 6469-3.

3.18 Voltage class B

Classification of an electric component or circuit with a maximum working voltage of (> 30 and ≤ 1000) V a.c. or (> 60 and ≤ 1500) V d.c., respectively.

Please note: Symbols can be referenced as per ISO 12405 – 4: 2018

3.19 Device under Testing (DUT)

Battery pack or battery system

4. Testing guidelines and requirements

The schedule is only limited to high-energy lithium-ion traction battery packs and systems. Hence the testing methodology mentioned in 'ISO 12405 Part 4: 2018' (as amended from time to time) *Test procedure for performance testing of high energy battery packs* must be followed to determine the specific energy, energy efficiency and cycle life of the pack and system.

4.1 Tolerance Limit

There is no negative tolerance for star rating band; the performance testing parameters must be at par or better than the star rating band threshold. The accuracy of external measurement equipment shall be as per tolerances defined in section 5.1.2 of ISO 12405-4: 2018.

4.2 Preconditioning cycles

The DUT shall be conditioned by performing some electrical cycles, before starting the real testing sequence, in order to ensure an adequate stabilization of the battery pack or system performance. The pre-procedure sequence shall be as stated in 6.1.2.2 of ISO 12405 - 4: 2018.

4.3 Standard cycle (SC)

The standard cycle (SC) shall be performed at RT (Room Temperature). The SC shall comprise a standard discharge (SDCH) followed by a standard charge (SCH).

4.3.1.1 Standard Discharge (SDCH): Standard Discharge shall comprise of the following:

a) Discharge rate: C/3 or other specific discharge rate according to the specifications given by the supplier.

b) Discharge limit: according to the specifications given by the supplier.

c) Rest period after discharge to reach a stable condition: 30 minutes or a thermal equilibration at RT of the DUT is reached.

4.3.1.2 Standard charge (SCH): Standard Charge shall comprise of following:

a) Charge procedure and end of charge criteria: C/3 or another specific charge rate according to the specifications given by the supplier.

b) The specifications shall cover end of charge criteria and time limits for the overall charging procedure. In any case, the total charge procedure shall be completed within 8 h.

c) Rest period after charge: 60 minutes

4.4 Capacity & Specific Energy at Room Temperature

4.4.1 Purpose

This test measures DUT capacity in A·h at constant current discharge rates. For high-energy battery packs and systems the constant current discharge rates shall be corresponding to the suppliers rated C/3 capacity in A·h (e.g., if the rated three hour discharge capacity is 45 A·h, the discharge rate is 15 A). The three hour rate (C/3) is used as reference for static capacity and energy measurement and as a standard rate for pack and high-energy system level testing. In addition, if applicable, the 1C, 2C and the maximum permitted C rate shall be performed for capacity determination to meet the high-energy system requirements. Discharge shall be terminated on supplier specified discharge voltage limits depending on discharge rates and temperature.

The test methodology for high energy battery packs shall be as per 7.1.2.2 ISO 12405-Part (4): 2018.

The Capacity (A.h) of high energy battery packs and systems determined at C/3 and RT from the above test procedure will be considered for the calculation of specific energy for the purpose of this program.

Weight (kg) of the cell assembly of the DUT (i.e. weight of one cell * total no of cells) shall be considered while calculating the specific energy (Wh/kg) for the purpose of this program.

4.5. Energy efficiency at Fast charging

4.5.1 Purpose

The purpose of the energy efficiency at fast charging test is to determine the energy efficiency at different fast charging levels. This test applies to high-energy packs and battery systems only.

4.5.2 Test Procedure:

The test shall be performed with battery pack/systems at RT, 0 °C and Tmax (45 ± 2)°C and three different fast charging levels (1C, 2C and Ic,max). After thermal equilibration and conditioning of the DUT by a standard cycle, the DUT shall first be discharged via a standard discharge followed by a fast charge with a starting current of 1C, 2C and Ic,max. The charge rate, the maximum charge current Ic,max shall follow the requirement delivered by the supplier. The test sequence shall be performed as specified in table below.

Table 1 — Test sequence energy efficiency at fast charging test

Step	Procedure	Ambient temperature
1.1	Thermal equilibration	RT
1.2	Standard charge (SCH)	RT
1.3	Standard Cycle (SC)	RT
2.1	Standard discharge (SDCH)	RT
2.2	Fast Charge with 1C	RT
2.3	Rest period for 60 min at open power supply circuit	RT
2.4	Standard Cycle (SC)	RT
2.5	Standard discharge (SDCH)	RT
2.6	Fast Charge with 2C	RT
2.7	Rest period for 60 min at open power supply circuit	RT
2.8	Standard Cycle (SC)	RT
2.9	Standard discharge (SDCH)	RT
2.10	Fast Charge with Ic,max	RT
2.11	Rest period for 60 min at open power supply circuit	RT
3.1	Standard Cycle (SC)	RT
3.2	Thermal equilibration	0 °C
4.1	Standard discharge (SDCH)	0 °C
4.2	Standard Charge with C/3	0 °C
5.1	Thermal equilibration	RT
5.2	Standard charge (SCH) for top off	RT
5.3	Standard Cycle (SC)	RT
5.4	Thermal equilibration	(45 ± 2)°C
6.1	Standard discharge (SDCH)	(45 ± 2)°C
6.2	Fast Charge with 1C	(45 ± 2)°C
7.1	Thermal equilibration	RT
7.2	Standard charge (SCH) for top off	RT
7.3	Standard Cycle (SC)	RT
7.4	Thermal equilibration	(45 ± 2)°C
8.1	Standard discharge (SDCH)	(45 ± 2)°C
8.2	Fast Charge with 2C	(45 ± 2)°C
9.1	Thermal equilibration	RT
9.2	Standard charge (SCH) for top off	RT
9.3	Standard Cycle (SC)	RT
9.4	Thermal equilibration	(45 ± 2)°C
10.1	Standard discharge (SDCH)	(45 ± 2)°C
10.2	Fast Charge with Ic,max	(45 ± 2)°C
11.1	Thermal equilibration	RT

Step	Procedure	Ambient temperature
11.2	Standard charge (SCH) for top off	RT
11.3	Standard Cycle (SC)	RT

 # If Ic,max is less than 2C, then the test shall be performed at C/3, 1C & Ic,max.

a) All discharge tests shall be terminated at the supplier's discharge voltage limits.
b) All fast charge tests shall follow or shall be terminated at the supplier's requested limits.
c) The sampling rate for test data during testing is recommended to be <= 50 ms.
d) **Calculate energy efficiency for the following SOCs:**
   i. From SoC at discharge test termination to the next rounded SoC decade and each following 10 % SoC increment up to the SoC level at fast charge termination,
   ii. From each rounded SoC decade following the discharge test termination to each following 10 % SoC increment up to the SoC level at fast charge termination.

Based on measured voltage and current data for each standard discharge (SDCH) and the following fast charge test, use the following formula for calculation of the requested energy efficiency values:

$$\eta = \left| \frac{\int_{t_{start}}^{t_{end}} U \cdot I_{discharge} \cdot dt}{\int_{t_{start}}^{t_{end}} U \cdot I_{charge} \cdot dt} \right| \times 100\ [\%]$$

4.5.3 The following data shall be reported:

i. Current, voltage, DUT temperature and ambient temperature versus time at each discharge test and the following fast charge;
ii. Discharged capacity in Ah, energy in Wh and average power in W at each discharge test;
iii. Charged capacity in Ah, energy in Wh and average power in W following each discharge test;
iv. The End of discharge Voltage (EODV) of all available cell voltage measuring points for all performed discharge tests;
v. Energy efficiency for specified Delta SoCs at each standard discharge – fast charge test.
vi. Average of all the efficiencies determined shall be considered for the S&L program.

Table 2: Energy Efficiency at various temperatures and charge rates

Energy Efficiency			
Charging Rates	**Temperature**		
	0^0C	**Room Temperature**	**(45+-2)^{0}C**
C/3		NA	NA
1C	NA		
2C	NA		
Ic,max	NA		
Avg. (%)	a	b	c
Overall arithmetic energy efficiency (%): Average of a, b and c			

 # If $I_{c,max}$ is less than 2C, then the test shall be performed at C/3, 1C & Ic,max.

4.6 Power and internal resistance

The power and internal resistance test is intended to determine the dynamic power capability, the ohmic resistance for discharge and charge conditions as well as the OCV of the DUT as a function of SoC and temperatures according to a realistic load profile derived from vehicle driving operation.

This test applies to battery packs and systems.

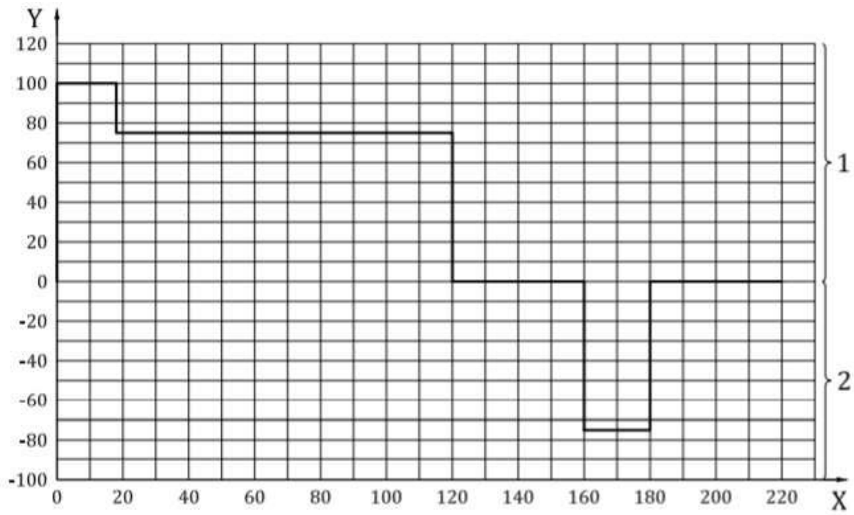
4.6.1 Pulse power characterization profile

The objective of this profile is to demonstrate the discharge pulse power (0,1 s, 2 s, 5 s, 10 s, 18 s, 18,1 s, 20 s, 30 s, 60 s, 90 s and 120 s) and regenerative charge pulse power (0,1 s, 2 s, 10 s and 20 s) capabilities at various SOC and temperatures. The test protocol uses constant current at levels derived from the supplier's maximum rated pulse discharge current Idp,max at the test temperature. In agreement with the customer, this value can be reduced. Only in case the DUT reaches the discharge voltage limit during discharge, the current shall be reduced such that the battery terminal voltage is maintained at the discharge voltage limit throughout the 120 s discharge pulse. The current of the regenerative charge pulse shall be kept constant and shall be calculated as 75 % of the discharge pulse current. Only in case the DUT reaches the charge voltage limit during charging, the current shall be reduced such that the battery terminal voltage is maintained at the charge voltage limit throughout the 20 s regenerative charge pulse.

The test profile shall start with an Idp,max discharge pulse for 18 s followed by a 0,75Idp,max discharge pulse for additional 102 s followed by a 40 s rest period to allow the measurement of the cell polarization resistance. After the rest period, a 20 s charge pulse with 75 % current rate of the Idp,max discharge pulse shall be performed to determine the regenerative charge capabilities. After the charge pulse, a rest period of 40 s shall follow (for timing and current see also Table 3 and Figure 1).

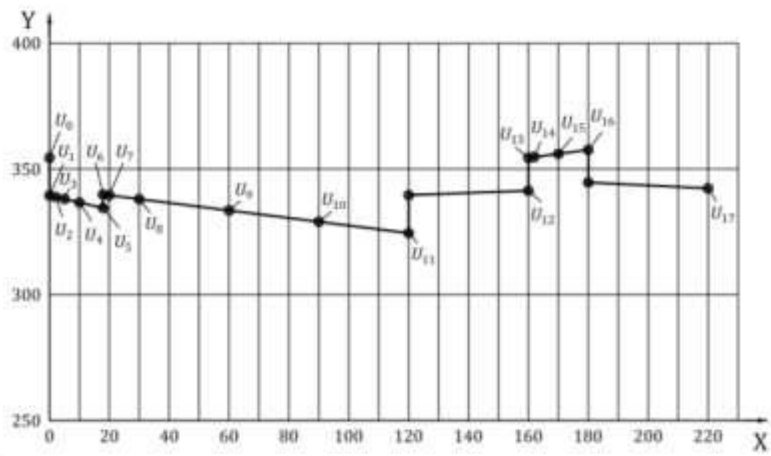
Table 3 – Pulse power characterization profile

Time increment [s]	Cumulative time [s]	Current
0	0	0
18	18	$I_{dp,max}$
102	120	0.75 $I_{dp,max}$
40	160	0
20	180	-0.75 $I_{dp,max}$
40	220	0



Key
X time [s]
Y current $I_{dp,max}$ [%]
1 discharge
2 charge

Figure 1: Pulse power characterization profile – current



Key
X time [s]
Y voltage of pack or system (example) [V]

Figure 2: Pulse power characterization profile – Voltage

For the peak power, regenerative power and resistance determination, the battery terminal voltage and current shall be measured at the times given in Table 4.

If the test equipment cannot provide the current value with the requested accuracy at the time of 100 ms after a change in the current profile, no related values for power and resistance shall be calculated for this specific test step.

Table 4: Measured Voltages and currents

Times [s]	Current Value	Voltage	Current
0	0	U_0	I_0
0.1	Idp,max	U_1	I_1
2	Idp,max	U_2	I_2
5	Idp,max	U_3	I_3
10	Idp,max	U_4	I_4
18	Idp,max	U_5	I_5
18.1	0.75 Idp,max	U_6	I_6
20	0.75 Idp,max	U_7	I_7
30	0.75 Idp,max	U_8	I_8
60	0.75 Idp,max	U_9	I_9
90	0.75 Idp,max	U_{10}	I_{10}
120	0.75 Idp,max	U_{11}	I_{11}
160	0	U_{12}	I_{12}
160.1	-0.75 Idp,max	U_{13}	I_{13}
162	-0.75 Idp,max	U_{14}	I_{14}
170	-0.75 Idp,max	U_{15}	I_{15}
180	-0.75 Idp,max	U_{16}	I_{16}
220	0	U_{17}	I_{17}

The following calculations for resistance and power shall be performed according to Table 5

Table 5: Calculation of resistance and power

Value	Formula	Δt [s]
0.1 s discharge resistance	R_i0.1s,dch=(U0-U1)/I1	0.1
2 s discharge resistance	R_i2s,dch=(U0-U2)/I2	2
5 s discharge resistance	R_i5s,dch=(U0-U3)/I3	5
10 s discharge resistance	R_i10s,dch=(U0-U4)/I4	10
18 s discharge resistance	R_i18s,dch=(U0-U5)/I5	18
18.1 s discharge resistance	R_i18.1s,dch=(U0-U6)/I6	18.1
20 s discharge resistance	R_i20s,dch=(U0-U7)/I7	20
30 s discharge resistance	R_i30s,dch=(U0-U8)/I8	30
60 s discharge resistance	R_i60s,dch=(U0-U9)/I9	60
90 s discharge resistance	R_i90s,dch=(U0-U10)/I10	90

Value	Formula	Δt [s]
120 s discharge resistance	R_i120s,dch=(U0-U11)/I11	120
Overall discharge resistance	$R_i$dch=(U12-U11)/I11	40
0.1 s charge resistance	R_i0,1s,cha=(U12-U13)/I13	0.1
2 s charge resistance	R_i2s,cha=(U12-U14)/I14	2
10 s charge resistance	R_i10s,cha=(U12-U15)/I15	10
20 s charge resistance	R_i20s,cha=(U12-U16)/I16	20
Overall charge resistance	R_i cha=(U16-U17)/I17	20
0.1 s discharge power	P0.1s,dch=U1*I1	0.1
2 s discharge power	P2s,dch=U2*I2	2
5 s discharge power	P5s,dch=U3*I3	5
10 s discharge power	P10s,dch=U4*I4	10
18 s discharge power	P18s,dch=U5*I5	18
18.1 s discharge power	P18.1s,dch=U6*I6	18.1
20 s discharge power	P20s,dch=U7*I7	20
30 s discharge power	P30s,dch=U8*I8	30
60 s discharge power	P60s,dch=U9*I9	60
90 s discharge power	P90s,dch=U10*I10	90
120 s discharge power	P120s,dch=U11*I11	120
0.1 s charge power	P0.1s,cha = U13*I13	0.1
2 s charge power	P2s,cha = U14*I14	2
10 s charge power	P10s,cha = U15*I15	10
20 s charge power	P20s,cha=U16*I16	20
open circuit voltage	Uocv=U17	

4.6.2 Test Procedure

The test shall be performed at six different temperatures (40 °C, RT, 0 °C, −10 °C, −18 °C and −25 °C) and shall cover a SoC range of 90 % to 20 % within five steps (90 %, 70 %, 50 %, 35 %, 20 %) whereas the last step at 20 % SoC shall only be performed if the maximum discharge current of the DUT is equal to or less than a 5C current rate in order to avoid a deep discharge of the DUT.

Prior to each test temperature, the DUT shall be conditioned at RT according to the thermal equilibration requirements provided in 5.1 of ISO 12405-4:2018 followed by a standard charge (SCH) for top off and a standard cycle (SC).

Then the DUT shall be conditioned at the specified test temperature according to the thermal equilibration requirements provided in 5.1 of ISO 12405-4:c2018 followed by a standard charge (SCH). The standard charge (SCH) is requested in order to condition the DUT to 100 % SoC at the specified test temperature prior to the pulse power characterization test profile.

In the next step, the fully charged DUT shall be discharged with a C/3 rate to the initial SoC of 90 % followed by a minimum 30 min rest period. A 108 s discharge with a C/3 rate will decrease the SoC level by 1 %.

Then the pulse power characterization profile as described in 4.6.1 shall be performed.

The next SOC steps (70 %, 50 %, 35 %, and 20 %) shall be reached by a C/3 discharge followed by a 30 minutes rest period. Then the pulse power characterization profile as described above shall be performed at each mentioned SoC step. The amount of electric charge [Ah] withdrawn during the previous power characterization profile needs to be taken into account when adjusting the SoC level to the next following step by a C/3 discharge.

At the end of the pulse power characterization profile at the 20 % SoC level, the standard charge (SCH) shall be performed.

Data sampling, especially for DUT voltage and current, shall be performed with an adequate sampling rate for the profile described in Figure 2 and Table 4. A minimum of 10 measuring points per step are required.

The complete test sequence shall be performed as specified in Table 6.

Table 6: Test sequence

Step	Procedure	Ambient Temperature [°C]
1.1	Thermal equilibration	RT
1.2	Top off Charge	RT
1.3	Standard Cycle (SC)	RT
2.1	Thermal equilibration	RT
2.2	Top off Charge	RT
2.3	Pulse power characterization	RT
2.4	Standard Charge (SCH)	RT
3.1	Thermal equilibration	RT
3.2	Top off Charge	RT
3.3	Standard Cycle (SC)	RT
4.1	Thermal equilibration	40
4.2	Top off Charge	40
4.3	Pulse power characterization	40
4.4	Standard Charge (SCH)	40
5.1	Thermal equilibration	RT
5.2	Top off Charge	RT
5.3	Standard Cycle (SC)	RT
6.1	Thermal equilibration	0
6.2	Top off Charge	0
6.3	Pulse power characterization	0
6.4	Standard Charge (SCH)	0
7.1	Thermal equilibration	RT
7.2	Top off Charge	RT
7.3	Standard Cycle (SC)	RT
8.1	Thermal equilibration	-10
8.2	Top off Charge	-10
8.3	Pulse power characterization	-10
8.4	Standard Charge (SCH)	-10
9.1	Thermal equilibration	RT
9.2	Top off Charge	RT
9.3	Standard Cycle (SC)	RT
10.1	Thermal equilibration	-18
10.2	Top off Charge	-18
10.3	Pulse power characterization	-18
10.4	Standard Charge (SCH)	-18
11.1	Thermal equilibration	RT
11.2	Top off Charge	RT
11.3	Standard Cycle (SC)	RT

12.1	Thermal equilibration	-25
12.2	Top off Charge	-25
12.3	Pulse power characterization	-25
12.4	Standard Charge (SCH)	-25
13.1	Thermal equilibration	RT
13.2	Top off Charge	RT
13.3	Standard Cycle (SC)	RT
14.1	Thermal equilibration	RT
14.2	Top off Charge	RT
14.3	Pulse power characterization	RT
14.4	Standard Charge (SCH)	RT

The following data shall be delivered by using the equations described in 4.6.1:

i. Discharge power for 0,1 s, 2 s, 5 s, 10 s, 18 s, 18,1 s, 20 s, 30 s, 60 s, 90 s and 120 s peaks as a function of SOC and temperature;

ii. Regenerative power for 0,1 s, 2 s, 10 s and 20 s peaks as a function of SoC and temperature;

iii. Discharge resistance for 0,1 s, 2 s, 5 s, 10 s, 18 s, 18,1 s, 20 s, 30 s, 60 s, 90 s and 120 s peaks as well as the overall resistance as a function of SoC and temperature;

iv. Charge resistance for 0,1 s, 2 s, 10 s and 20 s peaks as well as the overall resistance as a function of SOC and temperature;

v. Open circuit voltage as a function of SoC and temperature;

vi. Deviation from first and last test at RT, if any;

vii. Temperature versus time of the DUT at the specified tests;

viii. If the charge or discharge current had to be reduced due to voltage limits, the calculated internal resistance values shall be marked clearly in the protocol and in the result tables.

4.7 Life Cycle

In addition to other ageing factors (i.e. time, temperature), the energy throughput has significant influence on the lifetime of a battery.

In order to choose a relevant ageing profile relating to the energy throughput, real driving conditions shall be considered. That means the applied high C rates and SoC swing shall cover the vehicle demands in a realistic way. Further, the usable SoC range shall be covered by the energy cycling test. This is important in order to get reliable and significant data for lifetime prediction.

On the other hand, the battery system shall not be stressed excessively. Therefore, the thermal management and monitoring of the battery system is mandatory; in addition, certain rest phases are needed for equilibrium and cell balancing.

This section mentions steps dedicated to test battery systems used in dynamic discharge applications followed by a complete charging procedure.

This test applies to battery systems only.

4.7.1 Preparation:

During the test, it is necessary to maintain the DUT temperature by its cooling equipment within a temperature range between RT and 45 °C $\pm$ 2 °C (i.e. RT during rest periods, certainly higher during operation). If requested by the supplier, additional rest periods can be placed between the cycles in order to keep the DUT within the designated temperature range.

The cycle test is performed by combining two test profiles: one is the “dynamic discharge power profile A”, where the amount of discharged energy is significantly lower than the “dynamic discharge power profile B”. The profiles are shown in Figure 3 and Figure 4.

The SOC range shall be defined by the customer, otherwise the cycle test shall be performed between 100 % and 20 % SoC.

The cycle test shall be started from the upper limit of SoC with a sequence by performing the dynamic discharge power profile A, followed by the dynamic discharge power profile B and then followed by the dynamic discharge power profile A until SoC reaches the lower limit or the battery voltage reaches the lower voltage limit specified by the supplier. Within the next step, the battery system shall be charged according to the supplier's recommendation to the upper limit of SoC with the requirement to maintain the total time for the discharge–charge cycle including a rest time for cell balancing to 8 hours. This sequence of dynamic discharge power profiles including charging shall be repeated during the following 28 days. After these cycling activities the capacity and pulse power characterization tests shall be performed to determine the current status of the battery system. After this performance testing, the life cycling testing shall be continued until the test has been terminated according to the specified criteria;

The SoC limit can be detected by one of the following:

i. SoC calculated, i.e. by the BCU for a battery system test;

ii. Ah counted by external measurement;

iii. Battery voltage upper and lower limits defined by the supplier.

4.7.1.1 Test sequence battery system life cycle test for dynamic discharge applications

Table 7: Test sequence battery system cycle life test for dynamic discharge applications

Step	Procedure	Ambient temperature
1	Thermal equilibration	RT
2	Standard cycle (SC)	RT
3	Standard cycle (SC) for C/3 capacity determination	RT
4	Thermal equilibration	(45 ± 2)°C
5	Top off charge	(45 ± 2)°C
6	Standard cycle (SC) for C/3 capacity determination	(45 ± 2)°C
7	Thermal equilibration	RT
8	Standard cycle (SC)	RT
9	Cycling by performing the sequence of dynamic power profile A, followed by the dynamic discharge profile B and then followed by the dynamic discharge power profile A until: • SoC 20% • Battery voltage reaches lower limit defined by the supplier.	RT
10	Charging to 100% SoC as defined by the supplier with the following requirements: • Charging including cell balancing activities and rest time shall be finished at least 8h after starting the dynamic discharge profile A	RT
11	Repeat step 9 to 11 for a total of 28 days	
12	Thermal equilibration	RT
13	Standard cycle (SC)	RT
14	Standard cycle (SC) for C/3 capacity determination	RT
15	Thermal equilibration	RT
16	Top off charge	RT
17	Pulse power characterization	RT
18	Standard charge (SCH)	RT
19	Every 8 Weeks continue with step 20, otherwise step 9	
20	Thermal equilibration	(45 ± 2)°C
21	Top off charge	(45 ± 2)°C
22	Standard cycle (SC) for C/3 capacity determination	(45 ± 2)°C
23	Thermal equilibration	RT
24	Standard cycle (SC)	RT
25	Thermal equilibration	(45 ± 2)°C
26	Top off charge	(45 ± 2)°C
27	Pulse power characterization	(45 ± 2)°C
28	Thermal equilibration	RT
29	Standard cycle (SC)	RT
30	Continue with step 9	RT

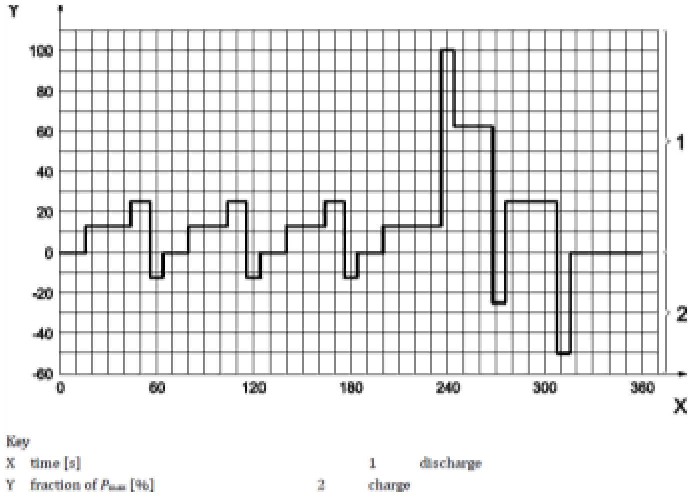


Figure 3: Profile for cycle life test – Dynamic discharge power profile A

Table 8: Time and power data- Dynamic discharge profile A

Step	Time increment [s]	Time cumulative [s]	Fraction of max. power [%]
1	16	16	0
2	28	44	12.5
3	12	56	25
4	8	64	-12.5
5	16	80	0
6	24	104	12.5
7	12	116	25
8	8	124	-12.5
9	16	140	0
10	24	164	12.5
11	12	176	25
12	8	184	-12.5
13	16	200	0
14	36	236	12.5
15	8	244	100
16	24	268	62.5
17	8	276	-25
18	32	308	25
19	8	316	-50
20	44	360	0

In this profile, the max. Power shall be the power value $P_{10s,dch}$, as per 4.6 at RT, 35 % SOC and t = 10 s unless customer and supplier have agreed on a reduction of this power value.

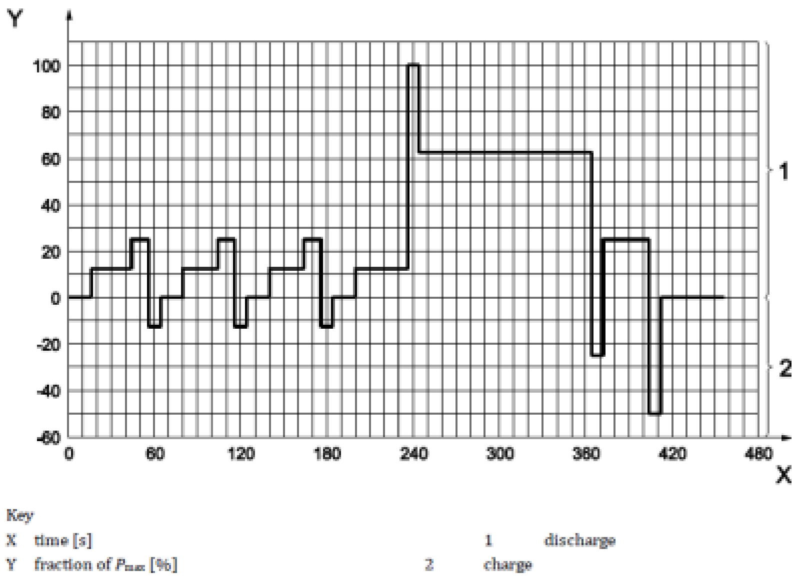


Figure 4: Profile for cycle life test – Dynamic discharge power

Table 9: Time and power data- Dynamic discharge power profile B

Step	Time increment [s]	Time cumulative [s]	Fraction of max. power [%]
1	16	16	0
2	28	44	12.5
3	12	56	25
4	8	64	-12.5
5	16	80	0
6	24	104	12.5
7	12	116	25
8	8	124	-12.5
9	16	140	0
10	24	164	12.5
11	12	176	25
12	8	184	-12.5
13	16	200	0
14	36	236	12.5
15	8	244	100
16	120	364	62.5
17	8	372	-25
18	32	404	25
19	8	412	-50
20	44	456	0

In this profile, the max. Power shall be the power value P10s,dch, as per 4.6 at RT, 35 % SoC and t= 10 s.

4.7.2 Conditions

Ambient: start at RT in a temperature chamber with adequate safety equipment.

Designated (or comparable) battery cooling system shall operate.

During cycling, the DUT electronic shall ensure that no cell limits will be exceeded, by achieving voltage limits as specified by the supplier. The current has to be reduced automatically to avoid any electrical and functional operation.

4.7.3 Monitoring and data logging

All available voltage and temperature sensor data shall be monitored and logged. The amount of stored data may be reduced by logging only during selected (critical) parts of the test sequences. Cumulated capacity which corresponds to the delta SoC shall be recorded in order to compare with the SoC value given by the BCU.

4.7.4. SOC determination

Due to ageing during the cycling test, a capacity loss is expected. Therefore, it is very important to provide a clear procedure to determine SoC over the whole test period. The rated capacity, determined above, specifies the range between 100 % SoC (fully charged) and 0 % SoC (fully discharged). For adjustment of the SoC values, the 100 % value shall be taken as basis.

4.7.5. End of test criteria

The cycle life test shall be terminated according to any of the following end of test criteria:

1. The cycle life test for dynamic discharge applications cannot be performed any longer, e.g. because limits are reached;

2. The retained capacity reached a level of 80% capacity that of beginning of life value.

3. The Requirements of the parameter check between the power cycling sequences according to Table 7 step 13 to 29 can no longer be fulfilled.

4.7.6. Capacity fade

The change of dischargeable capacity from the beginning-of-life value to some later point in time shall be reported periodically as capacity fade. The capacity fade, *C*fade, shall be expressed as a percentage of the initial BoL (Beginning of Life) capacity (C/3 at RT) as shown in the following equation:

$$C_{\text{fade}} = \left(1 - \frac{C_{\text{rt}}^{t_x}}{C_{\text{rt}}^{t_0}}\right) \times 100\ \%$$

where

$C_{\text{rt}}^{t_x}$ is the C/3 capacity at current test;

$C_{\text{rt}}^{t_0}$ is the rated C/3 capacity at BOL;

t_x is the time of the later C/3 capacity where capacity fade has to be determined;

t_0 is the time of the initial BOL C/3 capacity.

5. Rating plan/ labelling plan

This program shall rate high-energy battery packs and systems based on specific energy and cycle life of the battery pack/system categorized as per Basic Matrix Group (BMG) as mentioned below:

Table 10: Basic Matrix Group (BMG) matrix

Cycle Life Range*		Specific Energy (Wh/kg)				
		A	**B**	**C**	**D**	**E**
		≥100	**≥150**	**≥200**	**≥275**	**≥350**
1	**1000 to 1499**	BMG A1	BMG B1	BMG C1	BMG D1	BMG E1
2	**1500 to 1999**	BMG A2	BMG B2	BMG C2	BMG D2	BMG E2
3	**2000 to 3999**	BMG A3	BMG B3	BMG C3	BMG D3	BMG E3
4	**≥4000**	BMG A4	BMG B4	BMG C4	BMG D4	BMG E4

(*) Subject to revision based upon availability of life cycle test data in the course of implementation of the program.

A BMG shall comprise of a families each having a parent and child as defined in the subsequent paras. The battery packs/systems in a BMG shall be rated based on tested energy efficiency (η), the parent battery (highest capacity A.h) in every family has to undergo complete cycle life testing.

The star labelling scheme for Lithium-ion packs and systems:

Table 11: Star rating matrix

Star Level	Overall battery pack efficiency [%]	
	Min	Max
1 star	85	88
2 star	> 88	91
3 star	> 91	95
4 star	>95	98
5 star	>98	

Family of battery packs is defined as battery packs and systems that lie under the same BMG category and are equipped with the same BMS model type and cell type (Prismatic cell, cylindrical cells, etc.). The capacity (Ah) and model number of the battery pack/system may vary in a family.

The battery pack/system within a family which has the highest rated capacity (Ah) is defined as the parent battery pack/system and has to undergo complete cycle life testing.

6. Check testing

BEE registered battery pack and system samples would be picked up at random by BEE or its designated agencies from the market and tested at a BEE empaneled NABL accredited Lab at the expense of BEE. If the first sample fails, then a second check testing would be carried out at the same lab. Under second check testing, two similar battery packs/systems with same rated efficiency would be picked up again from the market randomly and both samples would have to meet the declared pack/system efficiency. Even if one sample fails to meet the declared pack/system efficiency during second check testing, the battery pack and systems and the related BMG will be treated as being in non-compliance with the prescribed BEE standards.

7. Eligibility Criteria

i. Till such time, safety standards for ACC traction battery modules are notified by BIS, battery packs eligible for registration under this program shall comply with the applicable safety regulations as per CMVR 1989 amended from time to time.

ii. The application for registration should be submitted with all applicable pre- requisite certificates and a test report from a BIS recognized/NABL accredited lab or lab accredited by signatory of ILAC /APAC.

8. Registration process/Fees

With regards the S&L scheme for Batteries, the manufacturer must first register his company under BEE scheme by making one- time payment of Rs. 25,000/- for MSME and Rs.1,00,000/- for rest of the manufacturers. This amount is refundable.

i. The application fees for each model is Rs. 2,000/-(Rupees two thousand only) and fees for renewal/degradation for each model will be Rs.1,000/- (Rupees One thousand only).

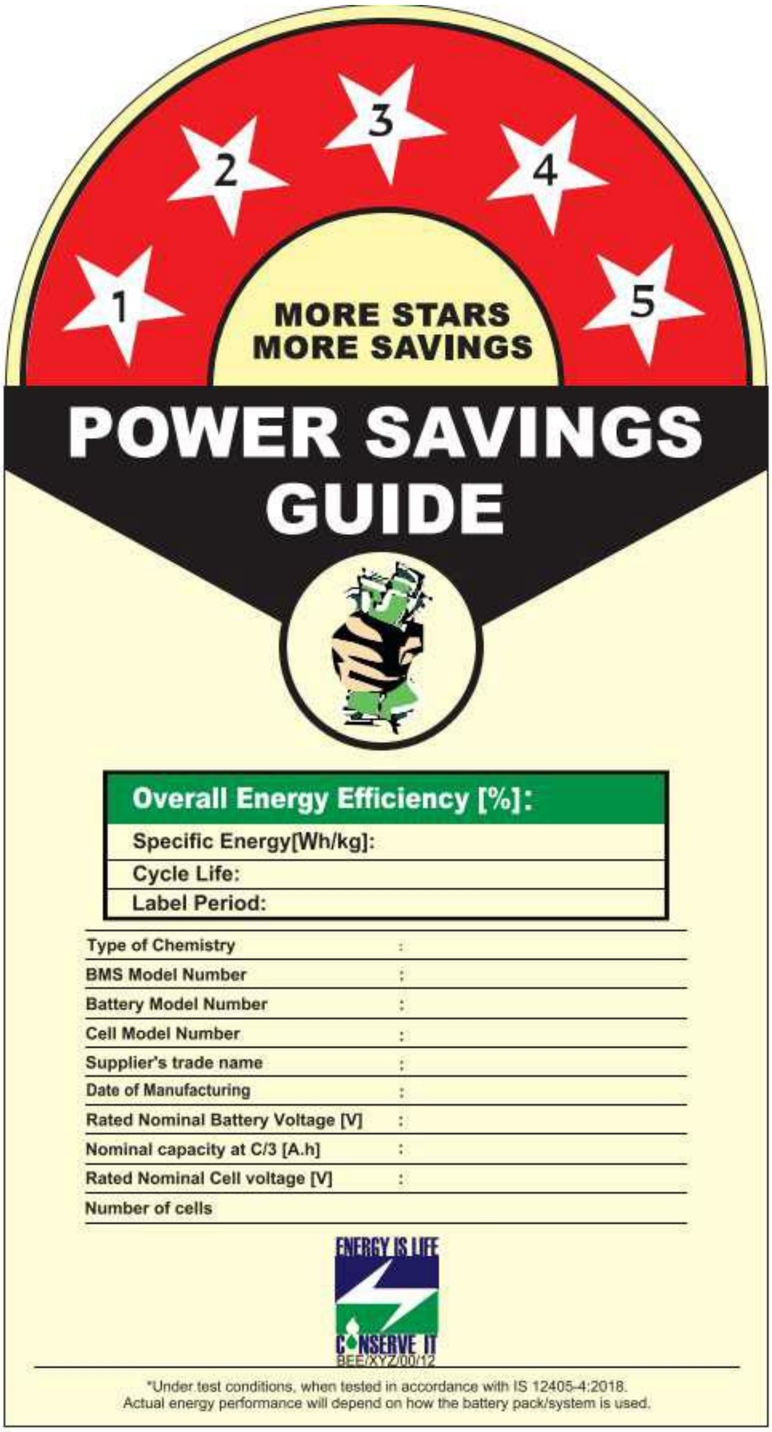
ii. Labelling fee for affixation of label on each battery pack/system rated from 1 star to 4 star is INR 50 per kW.h /- shall be charged by BEE.

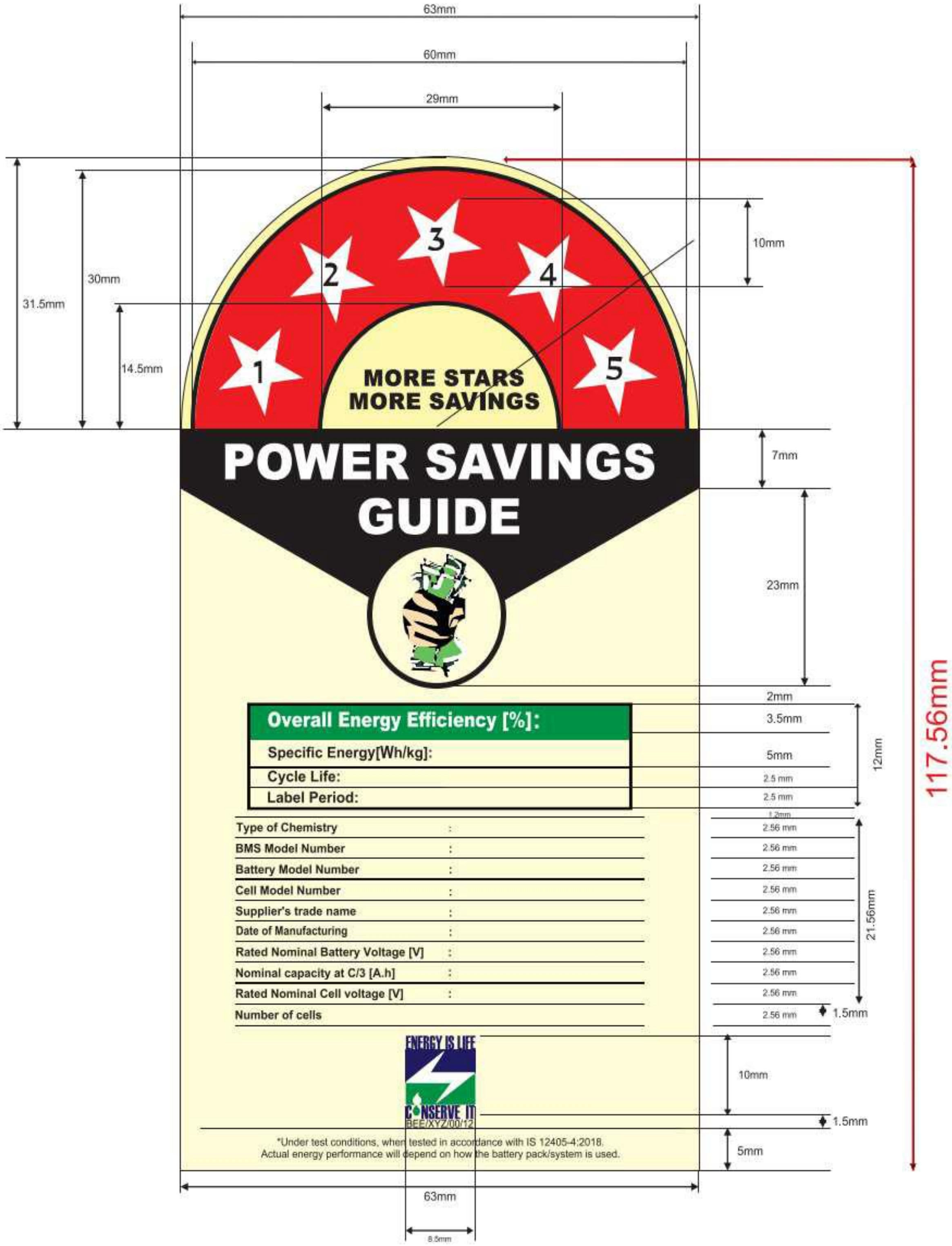
iii. However, the labelling fees for 5 star rated models would be kept as INR 25 per kW.h/- to promote higher efficiency battery.

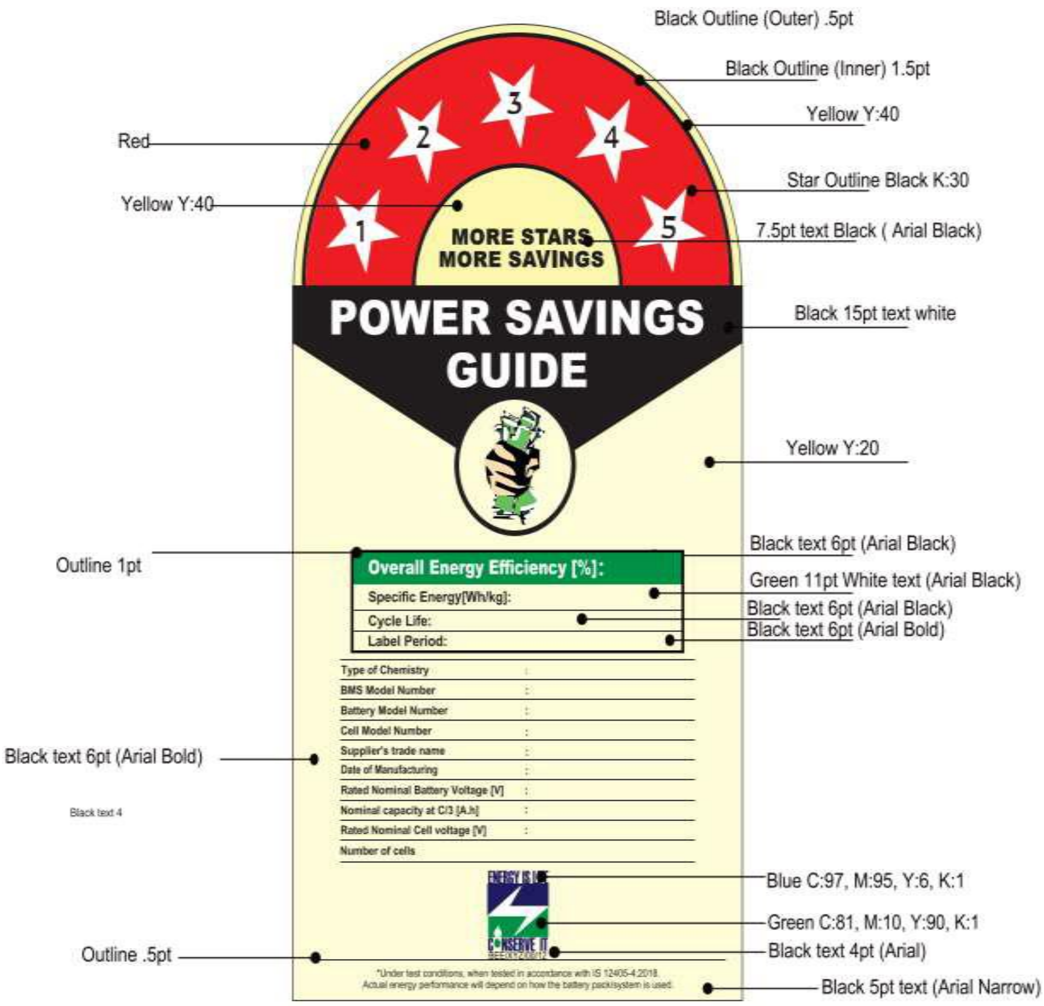
iv. The label validity period would be effective from the date of launch till 31st December 2022.

9. Label design and manner of display

- Placement: All batteries must display the label
- Material, Dimension and Shape: The label shall be of durable material and be printed as per the size given below.




63mm
60mm
29mm
31.5mm
30mm
14.5mm
10mm
1
2
3
4
5
MORE STARS
MORE SAVINGS
POWER SAVINGS
GUIDE
7mm
23mm
2mm
Overall Energy Efficiency [%]:
3.5mm
Specific Energy[Wh/kg]:
5mm
Cycle Life:
2.5 mm
Label Period:
2.5 mm
12mm
117.56mm
Type of Chemistry :
BMS Model Number :
Battery Model Number :
Cell Model Number :
Supplier's trade name :
Date of Manufacturing :
Rated Nominal Battery Voltage [V] :
Nominal capacity at C/3 [A.h] :
Rated Nominal Cell voltage [V] :
Number of cells
2.56 mm
21.56mm
1.5mm
ENERGY IS LIFE
CONSERVE IT
BEE/XYZ/00/12
10mm
1.5mm
*Under test conditions, when tested in accordance with IS 12405-4:2018.
Actual energy performance will depend on how the battery pack/system is used.
5mm
63mm


Black Outline (Outer) .5pt
Black Outline (Inner) 1.5pt
Yellow Y:40
Red
Star Outline Black K:30
Yellow Y:40
7.5pt text Black (Arial Black)
1
2
3
4
5
MORE STARS
MORE SAVINGS
POWER SAVINGS
GUIDE
Black 15pt text white
Yellow Y:20
Black text 6pt (Arial Black)
Outline 1pt
Overall Energy Efficiency [%]:
Green 11pt White text (Arial Black)
Specific Energy[Wh/kg]:
Black text 6pt (Arial Black)
Cycle Life:
Black text 6pt (Arial Bold)
Label Period:
Type of Chemistry :
BMS Model Number :
Battery Model Number :
Cell Model Number :
Black text 6pt (Arial Bold)
Supplier's trade name :
Date of Manufacturing :
Black text 4
Rated Nominal Battery Voltage [V] :
Nominal capacity at C/3 [A.h] :
Rated Nominal Cell voltage [V] :
Number of cells
Blue C:97, M:95, Y:6, K:1
Green C:81, M:10, Y:90, K:1
CONSERVE IT
Black text 4pt (Arial)
Outline .5pt
*Under test conditions, when tested in accordance with IS 12405-4:2018.
Actual energy performance will depend on how the battery pack/system is used.
Black 5pt text (Arial Narrow)

APPENDIX -A: Examples of data sheets for battery pack and system testing

Supplier			
Company			
Address			
Internet Address			
Contact Person			
Name			
Tel			
E-Mail			
Fax			
Type of Chemistry			
BMS Model Number			
Battery Model Number			
Cell Model Number			
Supplier's trade name			
Date of Manufacturing			
Nominal Battery Voltage [V]			
Nominal capacity at C/3 [A.h]			
Nominal Cell voltage [V]			
Number of cells			
Number of Cells Assemblies			
Type of Cathode Material			
Type of Anode Material			
Type of separator material			
Type of electrolyte			
	cell:	Cell Assembly:	Pack/system:
Mass[kg]			
Volume[dm3]			
Length[mm]			
Width[mm]			
Height[mm]			
Date of received battery pack/system at Lab [YYYY-MM-DD]			
Peripherals and instruction			
BCU	Yes:	No:	
Thermal Management	Yes:	No:	
Safety Devices	Yes:	No:	
Operating manual	Yes:	No:	

Battery Pack/system -Auxiliary equipment						
	BCU	Cooling	Connectors	Other	Tray	Total
Mass [kg]						
Volume [dm3]						
Length [mm]						
Width [mm]						

Height [mm]						
Power Consumption [W]						

Battery pack/system- operational conditions		
Charging		
Method		
Charging Time		
Temperature limits [deg-C]	min:	max:
Max. continuous Charge Current [A]		
Max. Charge Current [A], duration [s]		
Max. Battery temperature during charge [deg-C]		
Max. voltage during charge [V]		
Discharge		
Temperature limits [deg-C]	min:	max:
Max. continuous discharge Current [A]		
Max. discharge Current [A], duration [s]		
Min Voltage during discharge [V]		
Cut off Voltage [V]		

Performance figures

Test	**Conditions**		
Energy and Capacity at RT	Discharge Rate		
	C/3:	1C:	2C:
Number of cells :	Mass of one cell (kg):	Mass of total cell Assembly :	
Energy Efficiency			
Charging Rates	**Temperature**		
	0^0C	**Room Temperature**	(45 ± 2)°C
C/3		NA	NA
1C	NA		
2C	NA		
Ic,max	NA		
Avg. (%)	a	b	c
Overall arithmetic energy efficiency (%): Average of a, b and c			
Cycle Life :			

Tested by		**Approved by**	
Sign		Sign	
Name :		Name :	
Designation :		Designation :	
Date :		Date :	