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Application report
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The Use of Charge Factor and Reference Capacity in Test Programs

Introduction

In some test programs a defined relation between charged and discharged Ah is required. One definition of this relation is the **charge factor** CF:

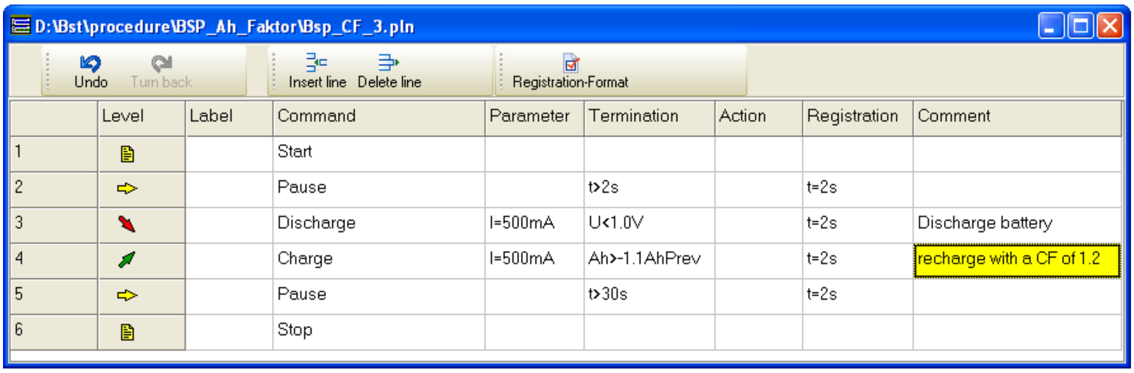
$$CF = \frac{\text{charged Ah}}{\text{discharged Ah}}$$

In some cases the CF is given by the charge regime, so the Ah to be charged depend on the Ah amount that was discharged. In this case a calculated termination criteria is required in the test program.

In other test procedures a reference capacity is needed, for example the capacity of the new battery. Different examples are given here.

Charging with a charge factor

The Basytec Software has different methods to work with a charge factor. The simplest method is the use of the internal value AhPrev that holds the Ah charged or discharged of the previous step. Figure 1 shows such a test plan.



	Level	Label	Command	Parameter	Termination	Action	Registration	Comment
1			Start					
2			Pause		t>2s		t=2s	
3			Discharge	I=500mA	U<1.0V		t=2s	Discharge battery
4			Charge	I=500mA	Ah>-1.1AhPrev		t=2s	recharge with a CF of 1.2
5			Pause		t>30s		t=2s	
6			Stop					

Figure 1: Simple method of a charge factor based charge

The test plan uses the internal value AhPrev, what is the charge amount of the previous step (here discharge step in line 3) multiplied by the charge factor (here 1.1) to terminate the charge step. The negative sign is necessary, as the discharge charge amount is negative (Nomenclature of the current: charging: positive current; discharging: negative current). The disadvantage of this method is the relation to the previous step. It does not work if there is another step between the discharge and the charge step, for example a Pause step or if the discharge is a more complex profile that uses more than one step. For this type of test a calculate statement must be used. Figure 2 shows such a test plan.

D:\Bst\procedure\BSP_Ah_Faktor\Bsp_CF_1.pln

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	Level	Label	Command	Parameter	Termination	Action	Registration	Comment
1			Start					
2			Calculate	AH_CF_13=13*As_D[DIS_1]/10				Charge factor of 1.3. Cause by integer arithmetic 1.3*X must be written as 13*X/10 As AS_D gives a positive value, no minus necessary
3		DIS_1	Discharge	I=0.25A	U<1.0V		t=1s	Here we measure the discharge capacity
4			Pause		t>1min		t=1s	
5			Charge	I=0.5A	Ah>AH_CF_13		t=5s	Terminate if Ah of this line reaches the calculated value
6			Pause		t>1s		t=1s	
7			Stop					

Figure 2: Using a charge factor with the calculate statement

The calculate statement in line 2 calculates the 130% of the discharge amount of line 3. As the calculate statement works with integer values (96 bit wide) mathematical operations must take this into account. Something like 1.3*As_D[DIS_1] would result in 1.0*As_D[DIS_1]. That is the reason for first multiplying by 13 and finally dividing by 10. The As_D[..] function always give a positive value, so there is no sign change necessary.
If a discharge profile (more than 1 line) is used, the profile should be grouped within a cycle-start, cycle-end syntax. If the label is than on the cycle-start line, all program steps in the cycle are used for the Ah calculation. An example is shown in Figure 3.

D:\Bst\procedure\BSP_Ah_Faktor\Bsp_CF_4.pln

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	Level	Label	Command	Parameter	Termination	Action	Registration	Comment
1			Start					Charge Factor Example
2			Calculate	AH_CF_13=13*As_D[DIS_1]/10				
3		DIS_1	Cycle-start		U<1.0V			Here we measure the discharge capacity for the whole cycle
4			Discharge	I=0.1A	t>5s		t=1s	
5			Discharge	I=0.5A	t>5s		t=1s	
6			Cycle-end	Count=0				
7			Pause		t>1s		t=1s	
8			Charge	I=0.5A	Ah>AH_CF_13		t=5s	
9			Pause		t>1s		t=1s	
10			Stop					

Figure 3: Using a charge factor for a none constant discharge profile

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The use of a reference capacity

Discharging or cycling a battery with a depth of discharge, that is normalized by the real measured capacity (and not by the rated capacity) can be done in a very similar way. Figure 4 shows an example.

D:\Bst\procedure\BSP_Ah_Faktor\Bsp_Ref_Capacity_2.pln

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	Level	Label	Command	Parameter	Termination	Action	Registration	Comment
1			Start					cycle a battery exacly with 60% DOD of initial capacity
2			Calculate	C60=-6*As_D[DIS_1]/10				Calculate 60% of the battery capacity measured in line 5 As_D is always positive
3			Charge	I=0.5A	t>3h UMax-U>5mV		t=10s	Charge the battery to 100% SOC
4		DIS_1	Discharge	I=0.25A	U<1.0V		t=10s	Measurement of the reference capacity
5			Cycle-start		U<0.8V			cycle with 60% dod
6			Charge	I=0.5A	t>3h UMax-U>5mV		t=10s	Charge the battery to 100% SOC
7			Pause		t>1min		t=10s	
8			Discharge	I=0.25A	Ah<C60		t=10s	Discharge 60%
9			Pause		t>1min		t=1s	
10			Cycle-end	Count=1000				1000 cycles
11			Pause		t>1s		t=1s	
12			Stop					

Figure 4: Cycling of a battery with 60% of its initial capacity

The battery is cycled with a depth of discharge of 60% of the rated capacity. You have to take care of the correct sign of the Ah counter. As during discharging the Ah counter has a negative sign (step 8) the reference value C60 must get a negative sign.

Figure 5 shows an example where the reference capacity is recalibrated every 50th cycle. As this example shows, line oriented values (here AS_D[DIS_1] are reset to 0 each time the line is entered by the program.

Figure 6 shows an example of a life cycle test that measures the initial capacity at the begin of the test and terminate cycling if the capacity falls below 80% of the initial value.

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D:\Bst\procedure\BSP_Ah_Faktor\Bsp_Ref_Capacity_3.pln

Undo | Turn back | Insert line | Delete line | Registration-Format

	Level	Label	Command	Parameter	Termination	Action	Registration	Comment
1			Start					cycle a battery exacly with 60% DOD and calibrate every 50 cycle
2			Cycle-start		U<0.8V			Cycle to repeat the reference measurement every 50th cycle
3			Calculate	C60=-6*As_D[DIS_1]/10				Calculate 60% of the battery capacity measured in line 5 As_D is always positive
4			Charge	I=0.5A	t>3h UMax-U>5mV		t=10s	Charge the battery to 100% SOC
5		DIS_1	Discharge	I=0.25A	U<1.0V		t=10s	Measurement of the reference capacity
6			Cycle-start					cycle with 60% dod
7			Charge	I=0.5A	t>3h UMax-U>5mV		t=10s	Charge the battery to 100% SOC
8			Pause		t>1min		t=10s	
9			Discharge	I=0.25A	Ah<C60		t=10s	Discharge 60%
10			Pause		t>1min		t=1s	
11			Cycle-end	Count=50				
12			Cycle-end	Count=20				total 1000 cycles
13			Pause		t>1s		t=1s	
14			Stop					

Figure 5: Cycling of a battery with 60% of its capacity. The reference capacity is measured every 50th cycle.

D:\Bst\procedure\BSP_Ah_Faktor\Bsp_Ref_Capacity_4.pln

Undo | Turn back | Insert line | Delete line | Registration-Format

	Level	Label	Command	Parameter	Termination	Action	Registration	Comment
1			Start					Terminate cycle life test if the battery capacity falls below 80% of initial capacity
2			Calculate	C80=-8*As_D[DIS_1]/10				Calculate 80% of the battery capacity measured in line 4 As_D is always positive
3			Charge	I=0.5A	t>3h UMax-U>5mV		t=10s	Charge the battery to 100% SOC
4		DIS_1	Discharge	I=0.25A	U<1.0V		t=10s	Measurement of the reference capacity
5			Cycle-start					cycle with 100% dod
6			Charge	I=0.5A	t>3h UMax-U>5mV		t=10s	Charge the battery to 100% SOC
7			Pause		t>1min		t=10s	
8			Discharge	I=0.25A	Ah<C80 U<1.0V	Goto Go_on Goto Eol	t=10s	Discharge 80% if not 80% reachd --> EOL
9		GO_ON	Discharge	I=0.25A	U<1.0V		t=10s	Go On discharging for 100% discharge
10			Pause		t>1min		t=1s	
11			Cycle-end	Count=10000				max. 10000 cycles
12		EOL	Pause		t>10s		t=1s	EOL: End Of Life
13			Stop					

Figure 6: Cycle life test that terminates if the battery capacity falls below 80% of initial capacity