BYSON
BE INSPIRED

BYSON Cable 25-Year Lifetime Instruction

Accurate cable lifetime prediction relies heavily on accelerated thermal aging exposures. The most important mythology for extrapolating cable performance under certain temperatures is based on the Arrhenius relationship. Byson Cable has conducted multiple tests to demonstrate that our PV cable has a minimum 25-year life time. If you want to know more, please download the complete report.

I. Objective

The document reviews test principles and test data with the purpose of explaining the expected 25-year service life of Byson cables.

II. Factors influencing the lifetime of PV cables for outdoor use

1. Thermal Aging (high or low temperature)
2. Light Aging (UV light)
3. Water (wetness or humidity)

In considering the PV cable's working environment (with two key factors: high temperature and UV light), this document mainly explains the cable lifetime by analyzing the above mentioned two principal causes. In addition, the document introduces a reliability test to explain the influence of secondary factors (low temperature, wetness or humidity) on cable lifetime.

III. PV Cable lifetime prediction under high exposure temperature (key factor)

3.1 Cable lifetime prediction relies heavily on accelerated thermal aging exposures. The most important mythology for extrapolating cable performance under certain temperatures is based on the Arrhenius relationship.

3.2 Temperature index: 120℃ (TI) (End-point 20000h, Elongation at break 50%, According to BS EN 60216-1)

3.3 Testing method according to BS EN 60216-2

3.4 Selected exposure temperatures and times: 145℃(10000 h), 165℃(800h), 185℃(100h)

3.5 Exposure temperatures and times selection principals and methods

3.5.1 Principal 1: select three temperatures. The chosen exposure temperatures should differ by equal intervals, normally by 20℃.

3.5.2 Principal 2: the lowest temperature exposure time >=5000 h, the highest temperature exposure time >=100 h (if possible, less than 500h)

Chart 1. Exposure temperatures and times

5.5 Exposure temperatures and times

For TI determinations, test specimens should be exposed to not less than three, preferably at least four, temperatures covering a sufficient range to demonstrate a linear relationship between time to end-point and reciprocal thermodynamic (absolute) temperature.

To reduce the uncertainties in calculating the appropriate thermal endurance characteristic, the overall temperature range of thermal exposure needs to be carefully selected, observing the following requirements:

a) the lowest exposure temperature shall be one which will result in a mean or median time to end-point of more than 5 000 h when determining TI (see also 5.1.3);

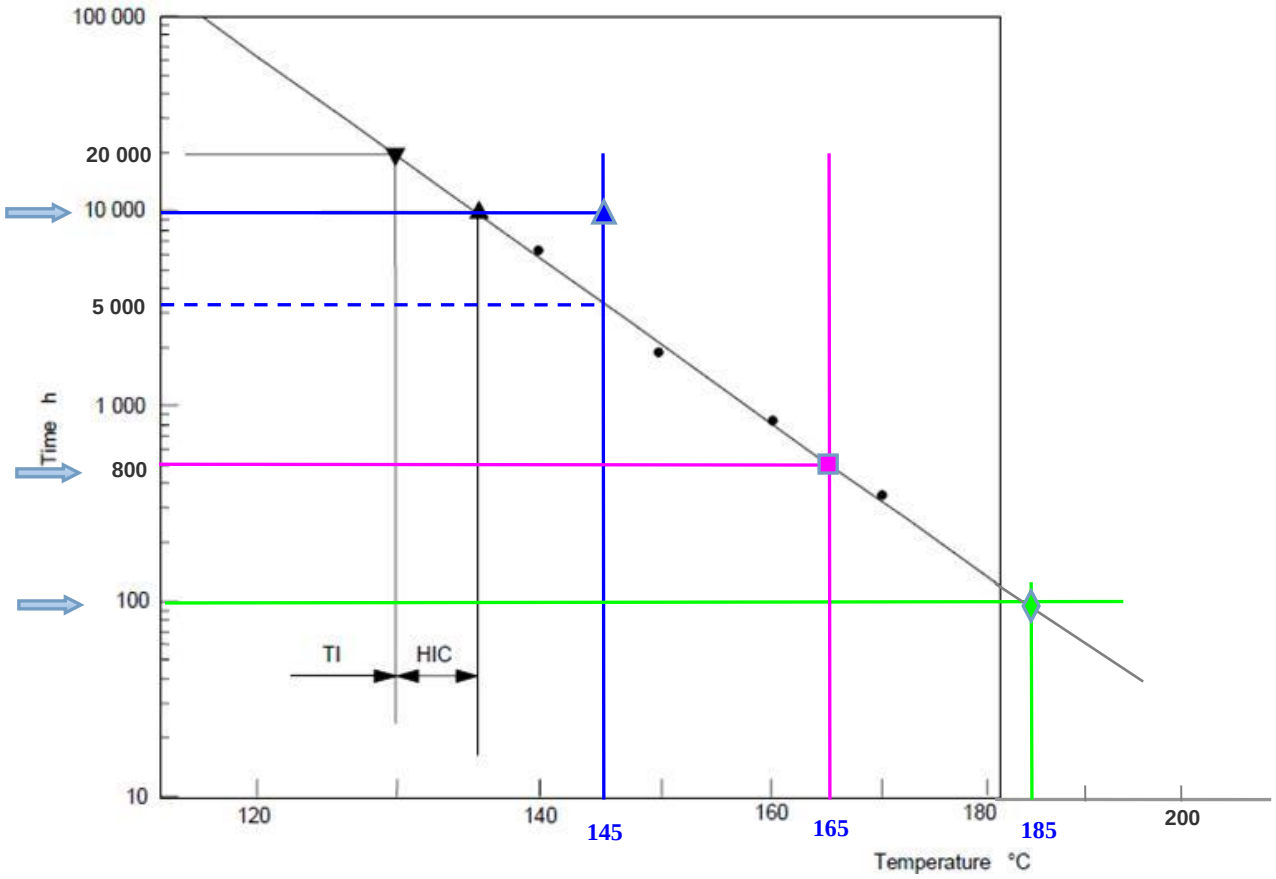
b) the extrapolation necessary to establish TI shall not be more than 25 K;

c) the highest exposure temperature shall be one which will result in a mean or median time to end-point of more than 100 h (if possible, less than 500 h).

3.5.3 Actual temperatures and times selection

Chart 2 serves for the selection of ageing temperatures and cycle durations when planning a thermal endurance test. Actual test results are shown in chart 3.

Chart 2. Temperatures and times selection



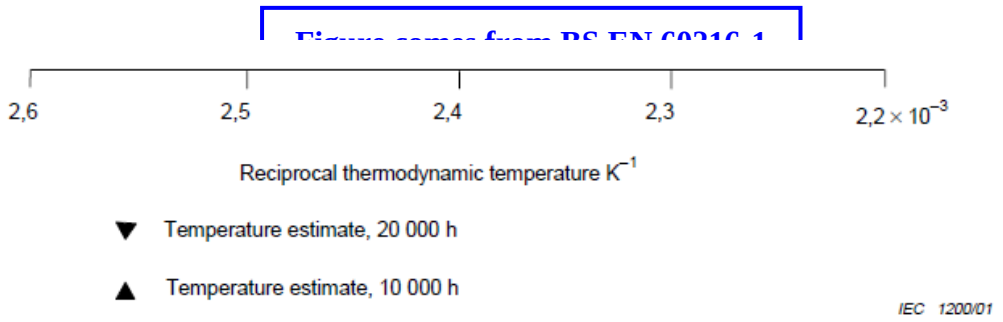


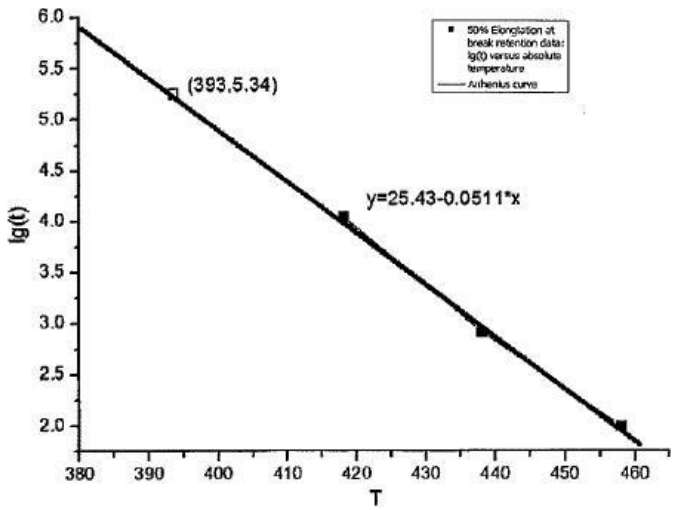
Figure 4 – Thermal endurance graph

3.6 Test results and Arrhenius curve

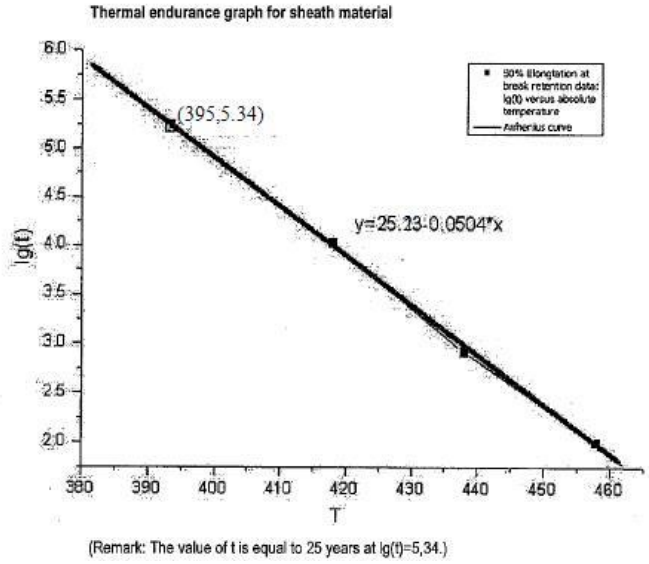
Chart 3. Test results and Arrhenius curve

Test sample	Time to end-point at exposure temperature 185°C hour	Specified time (min.) h	Time to end-point at exposure temperature 165°C hour	Time to end-point at exposure temperature 145°C hour	Specified time (min.) h	Obtained absolute temperature K	Absolute temperature (min.) K	
insulation	100	**100**	835	11242	**5000**	393	**393**	P
sheath	101	**100**	836	10365	**5000**	395	**393**	P

Thermal endurance graph for insulation material



(Remark: The value of t is equal to 25 years at lg(t)=5,34.)



(Remark: The value of t is equal to 25 years at lg(t)=5,34.)

3.5.1 Test Data in Process

Test sample	Elongation after 185℃/100h	Elongation after 165℃/800h	Elongation after 145℃ /10000h
Insulation	50%	52%	63%
Sheath	52%	52%	58%

3.5.2 Calculation for the Cable Life

1. Insulation life =t,

lg(t)=25.43-0.0511*(120+273)=5.3477 (120 is temperature index, 273 is absolute temperature K)

t=222,689h = 222689/(365*24) *Y= 25.42 Year

2. Sheath life =t1,

lg(t1)=25.23-0.0504*(120+273)=5.4228 (120 is temperature index, 273 is absolute temperature K)

t=264,728h = 264728/(365*24) *Y= 30.22 Year

Summary: From the above test, we can see the cable's insulation and jacket can be used for more than 25 years. （Min. life =25.42 Year）

IV. PV Cable lifetime prediction under UV radiation (key factor)

4.1 Accelerated weathering aging tests are used to evaluate the influence of UV radiation on cable lifetime prediction.

4.2 Testing methods according to UL1581 Sec 1200 & HD 605/A1

4.3 Test conditions

Chart 4. Condition of Weathering Exposure / UV-resistance

Temperature during drying	:	65°C
Relative humidity	:	65 %
Spray cycle: spraying	:	18 min
drying with xenon arc lamp	:	102 min
Power at wavelength 300nm to 400nm	:	60 W/m²

4.4 Test Results

Type	Jacket Color	Test Conditions	Require -ments	Test Results		Test Method	Note
Dual 4mm²	Black	63℃/ Duration:720h	Elongation At break Retention >=80%	97%	Pass	UL1581 Sec 1200	
			Tensile Strength Retention >=80%	102%			
		65 ℃ /65% R.H. Power: 60W/m² Duration: 1500h	Absence of cracks	No cracks	Pass	HD 605/A1	Elongation at Break: 90% Tensile Strength Retention: 97%
			Voltage test OK (6.5kV, 5min in the 20 ℃ water)	AC test OK			

4.5 Test Results and Cable Life Prediction

According to ISO4892-1（ Plastics - Methods of exposure to laboratory light sources - Part 1: General guidance ）and ASTM G151-06 (Exposing nonmetallic materials in Accelerated Test Devices that Use Laboratory Light Sources) guidelines, no laboratory exposure test can be specified as a complete simulation of actual use conditions in outdoor environments, due to the complexities of different use conditions in different locations. Therefore, laboratory test results are not used for determining the relative durability of materials for different environments. To predict the PV cable lifetime in this case, we have to make an analogy between PV cables and electric cables. UL44 standard specifies the requirements for thermoset-insulated cables

(After tests, Elongation at break retention should to be more than 80%, tensile strength retention should be

more than 80% according to the standard), which are similar to the requirements of PV cables. The actual service lifetime of electric cables (which have fulfilled the requirements of UL44) are 30 years. According to our actual obtained test data for Byson cables, our cables elongation at break retention is 90% and tensile strength retention is 97%. We therefore predict the PV cables lifetime is more than 30 years by this analogy.

Chart 5. UV Weather Resistance Test Guideline (From ASTM G 151-06)

4. Significance and Use

4.1 *Significance:*

4.1.1 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the accelerated test conditions will reproduce property changes and failure modes associated with end-use environments for the materials being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and outdoor exposures when setting up exposure experiments and when interpreting the results from accelerated exposure tests.

4.1.2 No laboratory exposure test can be specified as a total simulation of actual use conditions in outdoor environments. Results obtained from these laboratory accelerated exposures can be considered as representative of actual use exposures only when the degree of rank correlation has been established for the specific materials being tested and when the type of degradation is the same. The relative durability of materials in actual use conditions can be very different in different locations because of differences in UV radiation, time of wetness, relative humidity, temperature, pollutants, and other factors. Therefore, even if results from a specific exposure test conducted according to this practice are found to be useful for comparing the relative durability of materials exposed in a particular exterior environment, it cannot be assumed that they will be useful for determining relative durability of the same materials for a different environment.

4.1.3 Even though it is very tempting, calculation of an *acceleration factor* relating *x* h or megajoules of radiant exposure in a laboratory accelerated test to *y* months or years of exterior exposure is not recommended. These acceleration factors are not valid for several reasons.

4.1.3.1 Acceleration factors are material dependent and can be significantly different for each material and for different formulations of the same material.

4.1.3.2 Variability in the rate of degradation in both actual use and laboratory accelerated exposure test can have a significant effect on the calculated acceleration factor.

4.1.3.3 Acceleration factors calculated based on the ratio of irradiance between a laboratory light source and solar radiation, even when identical bandpasses are used, do not take into consideration the effects on a material of irradiance, temperature, moisture, and differences in spectral power distribution between the laboratory light source and solar radiation.

V. Reliability Test: low temperature test (low temperature, secondary factor)

5.1 Cold Impact Test

Type	Jacket Color	Test Conditions	Requirements	Test Results		Test Method	Note
Dual 4mm²	Black	-40℃/ 4h	Absence of cracks, ruptures or other damage.	No cracks, ruptures or other damage.	Pass	UL 4703/UL44	
			Absence of cracks	No cracks	Pass	EN 60811-1-4	

		-40℃/16h	Voltage test OK (6.5kV, 5min in the 20℃ water)	AC test OK		EN50395 , Clause 6	

5.2 Cold Bending Test

Type	Jacket Color	Test Conditions	Requirements	Test Results		Test Method	Note
Dual 4mm²	Black	-40℃/16h	Absence of cracks	No cracks	Pass	EN 60811-1-4 Clause 8.2	
			Voltage test OK (6.5kV, 5min in 20℃ water)	AC test OK		EN50395 , Clause 6	

VI. Reliability Test: long term resistance of insulation test and damp heat test (wetness or humidity, secondary factors)

6.1 Test method according to UL44

6.1.1 Test conditions: water temperature 90℃, test duration 12 weeks, continuous voltage rise AC600V

6.1.2 Test results (long term resistance of insulation test):

Type	Jacket Color	Test Conditions	Requirements	Test Results		Test Method	Note
Dual 4mm²	Black	90 ℃ immersion in water /12Weeks	Insulation resistance after test >= 1.0 GΩ.m	100GΩ.m	Pass	UL44 Clause 5.4.	

6.2 Test method according to EN60068

6.2.1 Test conditions: temperature 90℃, humidity 85% R.H, test duration 1000h

6.2.2 Test results (Damp Heat Test)

Type	Jacket Color	Test Conditions	Requirements	Test Results		Test Method	Note
Dual	Black	90℃ 85%R.H.	Variation of Elongation-	-5%	Pass	EN 60068-2-78	Test in Sharp: 3000 h,

4mm²		Duration: 1000h	at-Break<=-30%				Test Result: Pass. 
			Variation of Tensile Strength<=-30%	-6%	Pass		

6.3 Test Method: BS EN 60216-2

6.3.1 Test Conditions: temperature 185℃, test duration 120h

6.3.2 Test Results (Thermal Endurance Test)

Type	Jacket Color	Test Conditions	Require-ments	Test Results			Test Method	Note
Dual 4mm²	Black	90℃ Duration: 120h	Elongation>=50%	Insula-tion	50%	Pass	BS EN60216-2	Standards require elongation >=50% after 100h. The test duration has been extended to 120h so as to make sure the tested materials can meet the standards or even higher than the standards.
				Sheath	52%	Pass		

6.4 Below table shows reliability tests plan of Byson in order to ensure product performance stability.

No	Test item	Sampling frequency	Type of Test	Requirements	Test method
1	Conductor resistance (at 20℃)	First article test	T、S	Conform to Byson Technical data sheet	EN 50395,Clause 5
2	Min. Thickness of insulation	First article test	T、S	>=0.50mm	TUV 2PFG 1169 08.2007
				>=1.02mm	UL4703
3	Min. average thickness of insulation	First article test	T、S	>=1.14mm	UL4703
4	Min. Thickness of jacket	First article test	T、S	>=0.50mm	TUV 2PFG 1169 08.2007
				>=0.69mm	UL4703

5	Min. average thickness of jacket	First article test	T、S	>=0.76mm	UL4703
6	Diameter of insulation and jacket	First article test	R、T、S	Conform to Byson SOP	EN 50396,Clause 4.4
7	Ovality	First article test	T、S	<=15%	EN 50396,Clause 4.4
8	Printing friction resistance	1 sample/lot (500km=<1 lot <1000km)	T、S	Printing is legible	UL 1581, Section 1690
9	Elongation（Before aging）	First article test	T、S	>=150%	EN 0811-1-1,Clause 9.2 / UL 1581 section 400.1
10	Tensile strength(Before aging）	First article test	T、S	>=10.3Mpa	
11	Spark test	Total length	R	>=10kV	EN 50395,Clause 10
12	AC test on cable	1 sample/lot (100km=<1 lot <500km)	T、S	AC6.5 KV/5min No cracks	EN 50395,Clause 6
13	Insulation resistance test (at 20℃)	1 sample/lot (100km=<1 lot <500km)	T、S	>=1000Mohm.km	EN 50395,Clause 8
14	Aging test (150 ℃ +/-2℃,168hrs,TUV)	3 samples / 1 material lot	T、S	Remain rate >=70%	EN 0811-1-2,Clause 8.1
	Aging test(121℃+/-1℃,168hrs,UL)	3 samples / 1 material lot	T、S	Remain rate >=70%	UL 1581, Section 400
15	Hot set test (200+/-3 ℃ ,20N/cm²,Loading 15 min, Unload5min)	1 sample/lot (100km=<1 lot <500km)	T、S	Elongation under load <=100% Elongation nload<=25%	EN 60811-2-1,Clause 9
16	Cold bending (-40±2 ℃ 16h)(cable O.D.< 12.5mm)	3 samples / lot (1000km=<1 lot <1500km)	T、S	No cracks after test AC6.5KV/5min Pass	EN60811-1-4/8.2
17	Cold impact (-40±2 ℃ 16h)	3 samples / lot (1000km=<1 lot <1500km)	T、S	No cracks after test AC6.5KV/5min Pass	EN60811-1-4/8.5 / UL 4703

18	Pressure test at high temp. (140±3℃ , 4h)	3 samples / lot (1000km=<1 lot <1500km)	T、S	Depth of penetration <=50%, AC6.5KV/10min pass after cooling and unloading	EN60811-1-3

No	Test item	Sampling frequency	Type of Test	Requirements	Test method
19	Jacket shrinkage (120±3℃ 1h)	3 samples / lot (1000km=<1 lot <1500km)	T、S	Shrinkage<=2%	EN60811-1-3(11)
20	Flame test (IEC60332-1-2)	3 samples / jacket material lot	T、S	The distance from upper frame lower limb to start point of charing >=50mm The distance from upper frame lower limb to end point of charing <=540mm	IEC60332-1-2
	Flame test (VW for UL)	3 samples / jacket material lot	T、S	The fire duration after 5th time is less than 60 second. The flag fired less than 25%. The cotton cannot be ignited.	UL 1581 Section 1060
21	Ozone resistance	1 time / year (For 3rd party test)	T、S	Absence of cracks	EN 50396,Clause 8.1.3
22	Weathering-UV resistance	1 time / year (For 3rd party test)	T、S	Absence of cracks	HD 605/A1 / UL 1581 section 1200
23	Aging test at high temperature (185℃/120h)	3 samples / lot (1000km=<1 lot <1500km)	T、S	Elongation >=50%	EN 60216-2
24	Damp heat test	2 time / year	T、S	Variation of tensile strength: Max.-30%. Variation of elongation: Max. -30%.	EN 60068-2-78

25	Resistance against acid and alkaline solution	3 samples / lot (3000km=<1 lot <5000km)	T、S	Variation of elongation <=+/-30% Variation of tensile strength <=+/-30%. Elongation after test >=100%.	EN 60811-2-1
26	Absence of halogen (For cable test under fire condition)	1 time / year （For 3rd party test）	T、S	Acidity of gases: PH>=4.3. Conductivity<=10us/mm. Amount of halogen acid gas <=5mg/g.	EN50267-2-1/2

Note：R：Routine test：100% test

T：Type test periodically, but must test at follow conditions：

1) Raw material change;

2) Requested by 2nd or 3rd party.

S：Sampling test

To conclude, Byson cables with superior insulation and sheath performance can fulfill PV cable standard requirements and thus have a lifetime of more than 25 years.