WSD 2038 Issue 4

Specification for ZHSCG-35, Halogen-free, Power Cables for use in Photovoltaic Applications

May 2009

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PART 1 GENERAL REQUIREMENTS

1.0 Introduction

This specification covers ZHSCG-35, flexible, single-core, power cables primarily designed for application in photovoltaic systems. The cables comprise a class 5 conductor (in accordance with IEC 60228) and irradiation cross-linked, halogen-free, flame-retarded insulation and sheath materials that exhibit low smoke and toxicity in the event of fire.

Cables conforming to this specification have a voltage rating of 1800 Volts d.c. (1000 Volts a.c.) and are suitable for use in the temperature range from – 40°C to +125°C. The cables are mechanically robust and are also resistant to ozone, UV radiation and weathering. The cables have been approved to TÜV standard 2 Pfg 1169/08.2007 and UL Subject 4703. Any requalification testing needs to take into account the above specifications.

2.0 Test Methods

The test methods, where possible, are from international standards. Standards and documents referenced in this specification are shown in the associated Test Methods document.

3.0 Quality Assurance

Tyco Electronics is responsible for performing all inspection tests stated in this specification and can use internal or external inspection facilities and services acceptable to the buyer. Verification of materials and construction is performed at the appropriate stages of the manufacturing process. Inspection records will be kept complete and made available to the purchaser on request.

4.0 Qualification of Cable

Qualification consists of all tests in tables 2, 3 and 4 that are designated ‘Q’. The qualification samples are taken from production lots which have been manufactured under the Quality Control Plan.
Test methods are described in parts 2 and 3 of this document. Tests described in Table 3 can be performed on samples taken from cables or from extruded and beamed tapes, using the same compounds as the cable.

5.0 Quality Conformance Inspection

To ensure that the materials and the manufacturing processes are consistent and that the product meets the requirements of this specification, inspection and testing are used. The definition of the different tests and the frequency of testing are given in Table 1.

TABLE 1. Inspection Definitions

TEST TYPE	DEFINITION
Qualification (Q)	Tests conducted for qualification or re-qualification purposes only. These tests are carried out prior to first shipment and whenever a major change in process or material is made.
Lot/Batch (L)	Inspection lot or batch tests. These tests are carried out on each batch or lot. A batch or lot is any quantity of material manufactured on a substantially continuous basis.
100% Routine	Routine tests performed on 100% of the production length.

6.0 Preparation for Delivery

6.1 General

The delivery/packing conditions of cables are those described in the purchase order.

6.2 Identification and Labeling

Product is supplied unmarked in accordance with Tyco Electronics' standard terms and conditions. Special packaging and marking requirements shall be agreed between Tyco Electronics and the customer at the quotation stage.

6.3 Status of Delivery

The delivery of cables shall be accompanied by a certificate of conformity (summary routine test report).

7.0 Properties of Conductors and Finished Cables

7.1 Conductors

Tin-plated, soft-annealed, copper in accordance with IEC 60228 Class 5. Strands are to be clean and free from surface irregularities. Conductor dimensions, details of stranding and relevant cable dimensions are given in the appropriate Specification Control Drawing (SCD).

7.2 Finished Cable Properties

The property requirements and test regimes for finished cables are listed in tables 2 and 4. Table 3 refers to the testing of material properties conducted on extruded and beamed tapes. The clause numbers in tables 2, 3 and 4 refer to the relevant section in Parts 2 and 3 - Test Methods.

TABLE 2 TEST REQUIREMENTS

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Chart 3 - Tests for Halogen free PV wires

Clause No.	Property	Requirements (and relevant conditions)	Test Basis	Type
1.0	**Electrical Tests**			
1.1	Conductor Resistance		EN 50395 Section 5	Q, L
1.2	Voltage Test on complete wire AC **or** DC	- AC-test voltage 6.5kV		Q, L
		- DC-test voltage 15kV		
		Length of specimen 20m		
		Duration of test 5min		
		Temperature water quench 20 +/-5°C		
1.3	Absence of electrical fault	Voltage test at 10kVac	EN 50395 Section 10	R
1.4	Surface Resistance Sheath	Minimum Value 10^{9}Ohms	EN50395 Section 11	L
1.5	Insulating Resistance of complete wire	Minimum Value at 20°C 10^{14}Ohms * cm	EN 50395 Section 8	Q
		Minimum Value at 90°C 10^{11}Ohms * cm		
1.6	DC Stability	Test Conditions: 240h, 900vdc at 85 +/- 2°C	2 Pfg 1169/08.2007 Annex D	Q
		No breakdown		
2.0	**Dimensions**			Q, L
		Checking Accordance with Assembly Regulations	Inspection and manual check	
		Measurement of thickness of insulation	EN 50396 Section 4.1	
		Measurement of thickness of sheath	EN 50396 Section 4.2	
		Measurement of overall dimensions		
		- mean value	EN 50396 Section 4.4	
		- ovality </=15%	EN 50396 section 4.4	
3.0	**High Temperature Indentation Test**		EN 60811-3-1	Q
		Test Conditions: 240min at 140+/-3°C		
		- coefficient k = 0.6		
		Test Requirements:		
		- sag (max.) 50%		
		- voltage test 10 min after release and cooling down		
4.0	**Damp Heat Test**		EN 60068-2-78	Q
		Test conditions: 1000h at 90°C, 85%RH		
		Tensile Strength change +/- 30% max		
		Ultimate Elongation change +/- 30% max		
5.0	**Acid and alkaline resistance**		EN 60811-2-1 Section 10	Q
		Test duration / temperature 168h at 23°C		
		N Oxalic Acid		
		Tensile Strength change +/- 30% max		
		breaking elongation 100%,min		
		N Sodium Hydroxide		
		Tensile Strength change +/- 30% max		
		breaking elongation 100%,min		
6.0	**Testing Mutual Influence**		2 Pfg 1169/08.2007 Annex A	Q
		Test duration / temperature 168h at 135°C		
		Tensile Strength change +/- 30% max		
		Ultimate Elongation change +/- 30% max		
7.0	**Cold Impact Test at -40°C**		2 Pfg 1169/08.2007 Annex E	Q
		Test Conditions: 16h at -40 +/-2°C		
		No cracking		
8.0	**Cold Bending Test**		EN 60811-1-4 Section 8.2	Q
		Test Conditions: 16h at -40 +/-2°C	Wire o/dia	
		No cracking	<12.5mm	
9.0	**Cold Elongation Test**		2 Pfg 1169/08.2007 Chart 4	Q

TABLE 2 TEST REQUIREMENTS (continued)

10.0	**Test of ozone resistance of the complete cable**		EN 50396 Method B 8.1.3	Q
		- Test Conditions: 72h at 40 +/- 2°C, 55 +/-5%RH		
		- Ozone Concentration (portion in the volume)		
		No Cracking		
11.0	**Weathering / UV test**		HD 605 / A1 2.4.20	Q
		- Test Conditions: 720h at 63 +/- 2°C, 65 +/-5%RH		
		- Minimum Power 60 +/-2W/m²		
		at wave length 300nm to 400nm		
		- irrigation / drying time 18/102min		
		No Cracking		
12.0	**Dynamic Penetration Test**		2 Pfg 1169/08.2007 Annex F	Q
		Load constant @ 1N/s		
		Reqt: 50N x O/dia minimum		
13.0	**Notch Propagation**		2 Pfg 1169/08.2007 Annex G	Q
		0.05 notch		
		3h at +85, +23, or -15°C		
		3x mandrel followed by 0.5x rated voltage		
14.0	**Shrinkage Test on the finished wire**		EN 60811-1-3	Q
		Test Conditions: 1h at 120°C		
		Length "L" of the specimen 300mm		
		Maximum Shrinkage 2%		
15.0	**Performance under fire conditions**			Q, L
		Test of vertical flame propagation, complete wire	EN 60332-1-2	
		Verification of Halogens		
		Check for Halogen Contamination	2 Pfg 1169/08.2007 Annex B	
		Identification of Halogens - Test of Elements	2 Pfg 1169/08.2007 Annex C	

TABLE 3 TEST REQUIREMENTS (Testing of Material Properties)

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Chart 4 - Requirements for halogen free Insulation and Sheath Compounds

Clause No.	Property	Requirements (and relevant conditions)			Test Basis	Type
			Insulation	Sheath	Standard	
16.0	Mechanical Properties				EN 60811-1-1	Q
		Tensile strength minimum	6.5Mpa	8Mpa		
		Ultimate Elongation minimum	125%	125%		
17.0	Properties after Heat Ageing				EN 60811-1-2 Section 8.1	Q
		Test Duration / Temperature: 168h @ 150 +/-2°C				
		Tensile strength change maximum	-30%	-30%		
		Ultimate Elongation change maximum	-30%	-30%		
18.0	Thermal Expansion Test				EN 60811-2-1 Section 9	Q
		Load Duration / Temperature: 15min at 200 +/_3°C	15 / 200 +/- 3	15 / 200 +/-3		
		Mechanical Load: 20N/cm^2	20N/cm^2	20N/cm^2		
		Elongation under load, maximum	100%	100%		
		Elongation after load, maximum	25%	25%		
19.0	Thermal Endurance				EN 60216-2 / EN 50305.7.2	Q
		End point - either Tensile strength or winding test				
		Temperature index	120°C	120°C		
		Elongation at break	50%	50%		
		Winding test	2 *D*	2 *D*		
20.0	Cold Elongation Test				EN 60811-1-4 Section 8.4.4 & 5	Q
		Test Temperature	- 40 +/-2	- 40 +/-2		
		Elongation at break, minimum	30	30		

TABLE 4 TEST REQUIREMENTS

UL Subject 4703				
Clause No.	**Property**	**Requirements** (and relevant conditions)	**Test Basis**	**Type**
21.0	**Physical Properties of Core**			
21.1	**Unaged**	Tensile Strength: 10.3 MPa minimum	UL 1581, Clause 470	Q
		Ultimate Elongation: 150% minimum	UL1581, Table 50.231	
21.2	**Heat Ageing**	168 hours at 121°C	50.231 of UL 1581	Q
		Tensile Strength	UL 1581, Clause 470	
		70% retention minimum		
		Ultimate Elongation	UL 1581, Clause 470	
		70% retention minimum		
22.0	**Physical Properties of Jacket**			
22.1	**Unaged**	Tensile Strength: 10.3 MPa minimum	UL 1581, Clause 470	Q
		Ultimate Elongation: 150% minimum	UL1581, Table 50.231	
22.2	**Heat Ageing**	168 hours at 121°C	50.231 of UL 1581	Q
		Tensile Strength	UL 1581, Clause 470	
		70% retention minimum		
		Ultimate Elongation	UL 1581, Clause 470	
		70% retention minimum		
23.0	**720 hour weathering - jacket only**		Table 14.2 of UL 854	Q
		Tensile Strength	UL 1581, Clause 470	
		70% retention minimum		
		Ultimate Elongation	UL 1581, Clause 470	
		80% retention minimum		
24.0	**Insulation Resistance**	600Vac for 12 weeks in tap Water at 90°C. IR >3 MΩ.km.	UL 44, Clause 5.4	Q
25.0	**Flexibility test at low temperature**	-40°C	Section 583 UL 1581	Q
		No splitting, cracking		
26.0	**VW-1 Flame Test**	>60s flame, >25% flag	Section 1080 UL 1581	Q
		no flame particles		
27.0	**Capacitance and Relative Permittivity**	1,7 14 days at 90°C in tap water	Table 14.2 of UL 854	Q
			Section 1020 UL 1581	
28.0	**Deformation Test**	Insulation only: 30% maximum	Section 560 UL 1581	Q
			UL 44,Clause 5.12	
29.0	**Cold Bend Test of Complete Cable**	-40°C	Section 580 UL 1581	Q
		No splitting, cracking		

PART 2

SPECIFICATION FOR ZHSCG, HALOGEN-FREE, POWER CABLES FOR USE IN PHOTOVOLTAIC APPLICATIONS

TEST METHODS relating to: 2Pfg 1169/08.2007

– Requirements for cables for use in photovoltaic systems.

1.0 Referenced Documents (2Pfg 1169/08.2007)

IEC 60365-5-52	Erection of low voltage installations – Part 5: Selection and erection of electrical equipment – Chapter 52: Wiring Systems
EN 50267-2-1.	Common test methods for cable under fire conditions – Tests on gases evolved during combustion of materials from cables – Part 2-1: Procedures – Determination of the amount of halogen acid gas
EN 50267-2-2	Common test methods for cables under fire conditions – Tests on evolved during combustion from cables – Part 2-2: Procedures – Determination of degree of acidity of gases for materials by measuring pH and conductivity
EN 50305	Railway applications – Railway rolling stock cables having special fire performance – Test methods
EN 50395	Electrical test methods for low voltage energy cables
EN 50396	Electrical test methods for low voltage energy cables
EN 60068-2-78	Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state (IEC 60068-2-78)
IEC 60216-1	Electrical insulating materials - Properties of thermal endurance - Part 1: Ageing procedures and evaluation of test results
IEC 60216-2	Electrical insulating materials - Thermal endurance properties - Part 2: determination of thermal endurance properties of electrical insulating materials - Choice of test criteria
EN 60228	Conductors of insulated cables.
EN 60332-1-2	Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1kW pre-mixed flame
EN 60684-2	Flexible insulating sleeving - Part 2: Methods of test.
EN 60811-1-1	Insulating and sheathing materials of electric cables - Common test methods. Part 1-1: General application - Measurement of thickness and overall dimensions - Tests for determining mechanical properties.
EN 60811-1-2	Insulating and sheathing materials of electric and optical cables - Common test methods - Part 1-2: General application. Thermal ageing methods
EN 60811-1-3	Insulating and sheathing materials of electric and optical cables - Common test methods. Part 1-3: General application - Methods for determining the density – Water absorption tests - Shrinkage test
EN 60811-1-4	Insulating and sheathing materials of electric and optical cables - Common test methods - Part 1-4: General application - Tests at low temperature
EN 60811-2-1	Insulating and sheathing materials of electric and optical cables - Common test methods - Part 2-1: Methods specific to elastomeric compounds - Ozone resistance, hot set and mineral oil immersion tests
EN 60811-3-1	Insulating and sheathing materials of electric and optical cables – Common test methods - Part 3-1 Methods specific to PVC compounds - Pressure test at high temperature, test for resistance to cracking
HD 22.13	Rubber Insulated cables of rated voltages up to and including 450/750 V Part 13: Single and multicore flexible cables , insulated and sheathed with crosslinked polymer and having low emission of smoke and corrosive gases
HD 605	Power cables – Part 605 : Additional test methods
HD 60364-7-712	Electrical installations of buildings – Part 7-712: Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems

Clause 1.1 **CONDUCTOR RESISTANCE**

Test Method: EN50395

Requirements: 5.09 Ω/km maximum

Procedure: Test samples 1.1m in length are taken from each wire. The insulation is removed from either end to leave a length of insulation 1m in total. Using an ohmmeter the DC resistance of the conductor under the insulation is determined at the ambient temperature. The measured resistance is then corrected according to the values in IEC 60228 using the equation below;

$R_{20} = R_t \times k_t \times (1000/L)$

Where

R_{20} = conductor resistance at 20°C in ohms/km
Rt = Conductor resistance at measured the temperature in ohms/m
kt = temperature correction factor (From IEC 60228)
L= Length of wire in m

Clause 1.2 **VOLTAGE TEST ON COMPLETE WIRE**

Test Method: EN50395 cl.6

Requirements: No breakdown

Procedure: 20 metre samples of the cables are immersed (except for 150mm at each end) in a water bath at 20°C. The immersion time is 4 hours after which the wires are subject to 6.5kV at a frequency of 50 or 60Hz for 5 minutes

Clause 1.3 **INSULATION CONTINUITY PROOF TEST**

Spark test (10kV AC) in-process during cable manufacture.

Clause 1.4 **SURFACE RESISTANCE OF SHEATH**

Test Method: EN50395 cl.11

Requirements: The median of the three calculated values should not be lower than 10^9 ohms.

Procedure: Three sample lengths of 250 mm are cleaned with isopropyl alcohol and fitted with 2 helical copper electrodes, constructed from copper wire of between 0.2 and 0.6 mm in diameter. These are placed around the cable sheath at a distance of 100 ± 2 mm apart, such that they do not damage the sheath material. The samples are then conditioned at a temperature of 20 ± 2°C and a relative humidity of 65 ± 5% for a period of 24 hours. The samples are then removed from the conditioning chamber and subjected to 500 volts DC, applied between the two copper electrodes and the resistance is measured one minute after application of the voltage.

The measured resistance for each sample in ohms is multiplied by a/100 where "a" is the circumference of the sheath in mm.

Clause 1.5 **INSULATION RESISTANCE**

Test Method: EN 50395 Section 8.

Requirements: Minimum values
(i) at 20°C: 10^{14} ohms.cm
(ii) at 90°C: 10^{11} ohms.cm

Procedure: A 5 metre length of cable is immersed in a water bath (except for approximately 150 mm at each end) at a temperature of 20°C ± 5°C for a period of 2 hours. Following this, the specimen length is then checked for its insulation resistance by applying an AC test voltage of between 80 and 500 Volts (50 – 60 Hz) for a period of 1 minute between the conductor and the water.

The insulation resistance R expressed in MΩ.km shall be such that the coefficient K determined using the formula:

$K = L\ R / \text{Log}\ (D/d)$

R = measured insulation resistance (MΩ)
D = mean outer diameter of cable (mm)
d = mean diameter of core (mm)
L = immersed length (m)

The procedure shall also be carried out at a temperature of 90°C.

Clause 1.6 **DC STABILITY – LONG TERM RESISTANCE OF INSULATION**

Test Method: 2 Pfg 1169/08/2007, Annex D.

Requirements: No breakdown

Procedure: Samples of complete cable, in lengths of 5 metres, are coiled and immersed in 3% salt solution (except for approximately 250 mm at each end) and subjected to a temperature of 85 ±2°C for 240 ±2 hours.

A test voltage of 900 Volts dc is applied between the conductor, connected to the negative pole, and the salt solution for the duration of the immersion period.

Clause 2.0 **DIMENSIONS**

Test Methods: EN 50396 Section 4.

Requirements: See Table 3 below.

Procedure: The mean cable diameter shall be determined by taking the average of 3 measurements using a micrometer and the insulation and sheath thicknesses shall be measured with a calibrated microscope as per EN50396.

TABLE 3. CONSTRUCTION DETAILS

Product Description	Nominal Cross-sectional Area (mm^2)	Nominal* Wall Thickness of Insulation (mm)	Nominal Wall Thickness of Sheath (mm)	Overall Diameter of Cable (mm)		
				Minimum	Target	Maximum
ZHSCG-35-2.5	2.5	1.14	1.15	6.55	6.65	6.80
ZHSCG-35-4.0	4.0	1.14	0.95	6.80	6.90	7.00
ZHSCG-35-6.0	6.0	1.14	0.95	7.10	7.35	7.65

The UL also has a minimum requirement for the wall thickness of both the insulation and sheath that is stated in file E317230, Project 07CA5193 Description:

Conductor	Minimum Thickness of insulation at any point		Minimum Thickness of sheath at any point
18 – 10 AWG *Equivalent to:* 1.0mm^2 to 6mm^2	40 mils *Equivalent to:* 1.02mm		24 mils *Equivalent to:* 0.61mm

The TUV has a minimum wall thickness requirement for both insulation and sheath of 0.5mm.

* - Tyco terminology uses nominal to interpret the UL "minimum average thickness" within the manufacturing process. All thicknesses are measured at the thinnest point of insulation see EN60811-1-1.

Clause 3.0 **HIGH TEMPERATURE INDENTATION TEST**

Test Method: EN 60811-3-1

Requirements: Maximum indentation 50%

Procedure: The required loads are calculated for the test pieces from different cables. Three test pieces are then placed on the apparatus and the force applied on the blade, which is placed in a direction perpendicular to the axis of the sample.
The test pieces are heated at a temperature of 140°C for 6h.
After cooling, a test voltage is applied and the indentations are measured on a narrow strip cut from the test pieces.

Clause 4.0 **DAMP HEAT TEST**

Test Method: EN 60068-2-78

Requirements: Tensile Strength and Ultimate Elongation: -30% maximum change.

Procedure: The samples of cable shall be introduced into a test chamber, which are both at room temperature. The test chamber is then set to 90°C and 85% humidity and left for a period of 1000 hours.
After the conditioning period, the samples are removed and left at ambient temperature for 16 hours.
Samples are then tested for tensile strength and elongation at break.
Percentage retention of these properties, compared to control values, shall then calculated

Clause 5.0 **FLUID IMMERSION – Acid and alkaline resistance**

Test Method: IEC60811-2-1

Requirements: Tensile Strength: ±30% maximum change.
Ultimate Elongation: 100% minimum.

Procedure: Samples of at least 600mm are bent into “U” loops of a diameter approximately 10 times the outside diameter. These samples are then placed in the following fluids at the following temperatures for 168h with the ends protruding out of the fluid.

Fluids	Temperature
Oxalic Acid	23℃
NaOH	23℃

After the conditioning period, the samples are removed from the fluids and left at ambient temperature for 16 hours.

Samples are then tested for tensile strength and elongation at break. Percentage retention of these properties, compared to control values, shall then be calculated.

Clause 6.0 **TEST OF MUTUAL INFLUENCE**

Test Method: 2Pfg 1169/08.2007, Annex A
Requirements: Tensile Strength and Ultimate Elongation: ±30% maximum change.

Procedure: Five samples of cable shall be conditioned by hanging vertically for 168 hours in an air-circulating oven at a controlled temperature of 135℃ ± 2 ℃. Following conditioning, the samples are then tensile tested in accordance with IEC 60811-1-1.

Variation is recorded as the difference between the median value obtained after ageing and the median value obtained without ageing, expressed as a percentage of the latter.

Clause 7.0 **COLD IMPACT TEST AT -40℃**

Test Method: 2Pfg 1169/08.2007, Annex E
EN 60811-1-4

Requirements: No cracks

Procedure: After conditioning at -40℃ the test pieces are located in the test rig and then subjected to the hammer impact. Following recovery to room temperature, the samples shall then be examined visually for cracks.

Clause 8.0 **COLD BENDING TEST**

Test Method: EN 60811-1-4

Requirements: No cracks

Procedure: After conditioning at -40℃ the test pieces shall be bent tautly around a mandrel of diameter equal to 4 to 5 times the sample outside diameter. Following recovery to room temperature the samples are visually examined for cracks.

Clause 9.0 **COLD ELONGATION**

Not applicable - for cables with diameter greater than >12.5mm.

Clause 10.0 **OZONE RESISTANCE OF COMPLETE CABLE**

Test Method: EN 50396 Method B 8.1.3

Requirement: No cracks

Clause 11.0 **WEATHERING / UV RESISTANCE**

Test Method HD 605 / A1 2.4.20

Requirement: No cracks

Clause 12.0 **DYNAMIC PENETRATION TEST**

Test Method: Annex F, 2Pfg 1169/08.2007

Requirements: The mean value of the 4 test results must not be less than the minimum value F determined with following formula:

$F = 50 \times D$

D = cable diameter

Procedure: The test is carried out with a low voltage detection circuit at ambient temperature using a needle cutting edge.
The force on the cutting edge shall be increased at a constant rate of 1N/s until contact with the conductor.

Four tests are performed on each sample, and
the maximum force recorded at electrical contact.
After each test, the sample is moved forward 25mm
and rotated through an angle of 90° in a clockwise direction.

Clause 13.0 **TEAR RESISTANCE (notch propagation)**

Test Method: Annex F, 2Pfg 1169/08.2007

Requirements: No breakdown after voltage test

Procedure: Three samples of each cable are notched to a depth of 0.05mm of the sheath at 4 points equally spaced around the circumference and 25mm apart, in a plane perpendicular to the conductor. Samples are then conditioned at 85°C, ambient and -15°C for three hours before winding onto a 3x mandrel whilst at each conditioning temperature. After returning to ambient temperature, the samples shall then be subjected to a 6kV a.c. for 5 min.

Clause 14.0 **SHRINKAGE TEST ON FINISHED CABLE**

Test Method: EN 60811-1-3

Requirements: Maximum shrinkage: 2%

Procedure: Test samples 450mm in length shall be taken from each wire. The insulation is then removed from either end to leave a length of insulation 300mm in total. The insulation is then suspended horizontally in an oven, by the bare conductor ends, at 120 ± 2°C for 1 hour then removed and placed at room temperature to cool down, this cycle is then repeated 5 times. At the end of the 5 cycles the insulation is measured to determine the shrinkage.

Clause 15.0 **PERFORMANCE UNDER FIRE CONDITIONS**

Clause 15.1 **Flame Propagation**

Test Method: IEC 60332-1

Requirements: Charring must not extend above a point 50mm below the bottom of the top support.
Charring must not extend below a point greater than 540 mm from the lower edge of the top support.

Procedure: A sample of length 0.6 metre is taken and positioned vertically in a 3-sided chamber, using clamps 550 mm apart with the lower end of the cable at 50 mm from the bottom of the chamber.

The flame is set as described in IEC-695-2-4/1 specification and placed at an angle of 45 degrees to the specimen. The flame is then applied for the time specified dependent on cable diameter.

Clause 15.2 **Assessment of halogen**

Test Method: 2 Pfg 1169/08.2007 Annex C

Requirements: Chlorine and Bromine: ≤0.5%
Fluoride: ≤0.1%

Procedure: **Sodium fusion**

Place 200 mg – 250 mg of the sample into the bottom of a small soda glass test tube. Add 10 ml of distilled/de-ionized water to the evaporating basin and place this in the fume cupboard behind the safety screen. Whilst holding the test tube firmly with the test tube holder at an angle of 45° - 60° to the vertical, introduce a piece of freshly cut, clean sodium (about the size of a small pea) (200 mg – 250 mg) into the mouth of the test tube without allowing it to come into contact with the sample. With the safety screen in place, heat the sodium gently until it melts and runs down on to the sample (there may be a vigorous reaction when the molten sodium reaches the sample if halogens are present). Heat the tube gently for about 1 min, then more strongly until the lower 20 mm of the tube glows red hot. Plunge the red hot tube into the water in the evaporating basin, immediately placing the gauze on top. (The gauze prevents any loss of material when the tube shatters on contact with the water.) Allow any non reacted sodium to react before grinding up the solution and glass. Filter, and separate the filtrate into two equal portions.

Chlorine and bromine

To the first portion of the filtrate, add sufficient nitric acid to make the solution acidic. Boil this solution until its total volume has been reduced by half (this is to remove any HCN or H_2S, if present, which would interfere with the test). Add 1 ml silver nitrate solution; a white or yellowish-white precipitate indicates the presence of halogen (Cl, Br) in the original sample. (If the liquor is decanted, and the precipitate is white and readily soluble in dilute ammonia, then chloride is present.)

Fluorine

To the second portion of the filtrate, acidify with glacial acetic acid. Boil this solution until its total volume has been reduced by half. Add 2 to 3 drops freshly prepared zirconium lake reagent (equal volumes of:
a) Alizarin solution: 0,05 g Alizarin Red-S in 50 ml distilled water,
b) Zirconium solution: 0,05 g zirconium nitrate in 10 ml concentrated HCl diluted with 50 ml distilled water). Heat at 40°C for 1h. The presence of fluoride is indicated by the red/pink colouration being bleached to yellow.

Clause 16.0 **MECHANICAL PROPERTIES BEFORE AGEING**

Test Method: IEC 60811-1-1

Requirements:
Insulation:
Tensile Strength: 6.5MPa minimum
Ultimate Elongation: 125% minimum

Sheath:
Tensile Strength: 8.0MPa minimum
Ultimate Elongation: 125% minimum

Procedure: The tensile strength and elongation at break values shall be obtained according to IEC 60811-1-1. Die cut samples (dumbbells) are tested after first measuring the sample width and thickness using a dial gauge. The cross sectional area is then calculated according to the following formula;

$$A = WxT$$

Where;
T = Thickness of dumbbell
W = Width of dumbbell

A crosshead test speed of 250mm/min is to be used.

Clause 17.0 **PROPERTIES AFTER AGEING IN AN OVEN**

Test Method: IEC60811-1-2

Requirements: Insulation:
Tensile Strength and Ultimate Elongation: -30% maximum change.

Sheath:
Tensile Strength and Ultimate Elongation: -30% maximum change.

Procedure: Five die cut samples of insulation and sheath shall be tested in accordance with IEC 60811-1-2, clause 8.1. The samples are conditioned by hanging vertically for 168 hours in an air-circulating oven at a controlled temperature of 150 ± 2 °C. Following conditioning, the samples shall then be tensile tested in accordance with IEC 60811-1-1.

Clause 18.0 **THERMAL EXPANSION / HOT SET TEST**

Test Method: IEC 60811-2-1

Requirements: Insulation:
Elongation under Load: 100% maximum.
Elongation after cooling: 25% maximum.

Sheath:
Elongation under Load: 100% maximum.
Elongation after cooling: 25% maximum.

Procedure: Die cut samples of insulation and sheath are tested separately in accordance with IEC 60811-2-1, Clause 9.

The samples shall be suspended vertically in an air-circulating oven at a temperature of 200 ± 3°C for 15 minutes under a loading of 20 N/cm^2. Whilst still under load, the elongation of the sample is measured. The load is then removed and the samples are allowed to relax for 5 minutes at 200°C. The samples shall then be allowed to cool to ambient temperature and the elongation measured again.

Clause 19.0 **THERMAL ENDURANCE PROPERTIES**

Test Method: IEC 60216-2

Requirements: 120℃ for 20,000 hours

Procedure: A large number sample sets (10 sets of 3) are heat aged by exposure for selected periods of time at several fixed temperatures, e.g. 155°C, 165°C, and 180°C, 190℃. The experimental data is used to calculate an Arrhenius plot which assumes a linear relationship between the logarithms of the time to achieve as measured a 50% reduction in elongation at break - and the absolute temperature of exposure. Therefore, the time to failure at the maximum operating temperature can be determined.

Clause 20.0 **COLD ELONGATION TEST**

Test Method: IEC 60811-2-1

Requirements: Insulation: Ultimate Elongation: 30% minimum
Sheath: Ultimate Elongation: 30% minimum.

Procedure: Die cut samples of insulation and sheath are tested separately in accordance with IEC 60811-2-1, Clause 8.4.
The test shall be carried out on using a tensile testing machine fitted with a cooling device at a temperature of -40℃. The samples are preconditioned at this test temperature and tested for elongation at break.

PART 3

SPECIFICATION FOR ZHSCG, HALOGEN-FREE, POWER CABLES FOR USE IN PHOTOVOLTAIC APPLICATIONS

TEST METHODS relating to: UL Subject 4703

1.0 **Referenced Documents** (UL Subject 4703)

UL 1581	Reference Standard for Electrical Wires, Cables and Flexible Cords.
UL 854	Service Entrance Cables.
UL 44	Thermoset – Insulated Wires and Cables.

Clause 21.0 **PHYSICAL PROPERTIES OF INSULATION**

21.1 Unaged

Test Method: UL 4703
UL 1581, Clause 470

Requirements: Tensile Strength: 10.3MPa minimum
Ultimate Elongation: 150% minimum

Procedure: The tensile strength and elongation at break shall be carried out according to UL 1581, Clause 470. Tubular samples are tested after first measuring the external diameter of the wire (D) and the mean insulation thickness (δ) using a micrometer. The cross sectional area is calculated according to the following formula;

$$A = \Pi (D-\delta) \delta$$

Where;
D = Average external diameter of the wire in mm
δ = Average wall thickness in mm

A sample length of 100mm and a test speed 500mm/min shall be used.

21.2 Aged

Test Method: UL 4703
UL 1581, Clause 470
UL 1581, Clause 480

Requirements: Tensile Strength: 70% retention minimum.
Ultimate Elongation: 70% retention minimum.

Procedure: Five tubular samples of insulation shall be tested in accordance with UL 1581, Clause 480. The samples are conditioned by hanging vertically for 168 hours in an air-circulating oven at a controlled temperature of 121℃ ± 2 ℃. Following conditioning and after a 16 to 96 hours rest period at room temperature, the samples shall be tensile tested in accordance with UL 1581, Clause 470.

The aged samples shall have a minimum percentage retention of 70% of the tensile strength and elongation values obtained for the unaged samples when tested in accordance with UL 1581, Clause 470.

Clause 22.0 **PHYSICAL PROPERTIES OF JACKET**

22.1 Unaged

Test Method: UL 4703
UL 1581, Clause 470

Requirements: Tensile Strength: 10.3MPa minimum
Ultimate Elongation: 150% minimum

Procedure: The tensile strength and elongation at break shall be carried out according to UL 1581, Clause 470. Tubular samples are tested after first measuring the external diameter (D) and the mean thickness (δ) using a micrometer. The cross sectional area is calculated according to the following formula;

$$A = \Pi (D-\delta) \delta$$

Where;
D = Average external diameter of the wire in mm
δ = Average wall thickness in mm

A sample length of 100mm and a test speed 500mm/min shall be used.

22.2 Aged

Test Method: UL 4703
UL 1581, Clause 470
UL 1581, Clause 480

Requirements: Tensile Strength: 70% retention minimum.
Ultimate Elongation: 70% retention minimum.

Procedure: Five tubular samples of insulation shall be tested in accordance with UL 1581, Clause 480. The samples are conditioned by hanging vertically for 168 hours in an air-circulating oven at a controlled temperature of 121℃ ± 2 ℃. Following conditioning and after a 16 to 96 hours rest period at room temperature, the samples shall be tensile tested in accordance with UL 1581, Clause 470.

Clause 23.0 **WEATHERING JACKET ONLY**

Test Method: UL 854, Table 14.2

Requirements: Tensile Strength: 70% retention
Ultimate Elongation: 80% retention

Clause 24.0 **INSULATION RESISTANCE IN WATER – LONG TERM**

Test Method: UL 44, Clause 5.4

Requirements: At anytime during the 12 weeks immersion the insulation resistance value obtained must not be less than that listed in Table 35, (size dependant) and during the last 6 weeks of the immersion period the insulation resistance value obtained must not fall below 3GΩ.m.UL 44, Table 35, 600V, composite.

Procedure: A 15.24 metre (50 feet) sample of insulation shall be immersed in tap water for a period of 12 weeks at a temperature of 90°C. During the immersion period insulation resistance measurements are recorded as per UL 44, Clause 8.4.
An a.c. voltage equal to the rated voltage of the wire was applied to the sample at all times other than while measuring insulation resistance.

Clause 25.0 **FLEXIBILTY AT LOW TEMPERATURE**

Test Method: UL 4703
UL 854, Clause 21

Requirements: No cracking or splitting.

Procedure: Samples of complete wire shall be conditioned for 4 hours at -40°C. Following the conditioning period and while still in the conditioning cabinet, the wire is then bent 180° around a mandrel equal in diameter to 6 times the outside diameter of the wire. The sample shall then be secured in this position to the test mandrel and the assembly removed from the test cabinet.
The wire is then visually examined for any evidence of cracking or splitting.

Clause 26.0 **FLAMMABILITY – VW-1 (Optional part of UL Subject 4703)**

Test Method: UL 1581, Clause 1081

Requirements: A sample is considered a pass if:
(i) the indicator flag is not more than 25% burnt away
(ii) any flaming or glowing particles that drop do not ignite the cotton wool on the base of the test area,
(iii) flaming does not continue for more than 60 seconds following any application of the flame.

Procedure: The sample shall be subjected to 5, 15 second applications of a flame as described in 1080.1 using a bunsen burner to ASTM D 5025-99 calibrated to ANSI/ASTM 5207-98. The period between each application of the flame shall be 15 seconds, when the sample flame time is less than 15 seconds or immediately after any flaming that persists for longer than 15 seconds has ceased.
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Clause 27.0 **FLAMMABILITY – Vertical Flame test**

Test Method: UL 1581, Clause 1060

Requirements: A sample is considered a pass if:
(i) the indicator flag is not more than 25% burnt away
(ii) any flaming or glowing particles that drop do not ignite the cotton wool on the base of the test area,
(iii) flaming does not continue for more than 60 seconds following any application of the flame.

Procedure: The sample shall be subjected to 5, 15 second applications of a flame as described in 1080.1 using a bunsen burner to ASTM D 5025-99 calibrated to ANSI/ASTM 5207-98. The period between each application of the flame shall be 15 seconds, regardless of whether flaming of the sample ceases of it own accord within 15 seconds of the previous application.

Clause 28.0 **CAPACITANCE AND RELATIVE PERMITIVITY**

Test Method: UL 854, Table 14.2

Requirements: UL 1581, Clause 1020

Procedure: The capacitance of the sample is measured after immersion in tap water at 90°C at 1, 7 and 14 days. The test is carried out on 5 metre lengths of insulation only, having the centre 3.048m immersed.

The relative permittivity (dielectric constant) is calculated using:
$\acute{\varepsilon}_r = 13{,}600 \times C \times \log_{10} DIA \div dia$

$\acute{\varepsilon}_r$ = relative permittivity
C = capacitance of the 3.048 immersed sample
DIA = external diameter of the insulation
dia = internal diameter of the insulation

Clause 29.0 **DEFORMATION TEST OF INSULATION**

Test Method: UL 1581, Section 560

Requirements: Deformation: 30% maximum.

Procedure: Samples of insulation only shall be tested using the apparatus as described in UL 1581, Clause 560.4 / Figure 560.1.
Following separate preconditioning of the apparatus and samples in the test oven for one hour at the conditioning temperature of 121°C, the samples are then located onto the test apparatus under load for a further one hour. The load is then removed and the sample removed from the oven and allowed to cool to room temperature.

The percentage deformation is calculated by comparing the change in the external diameter of the sample before and after conditioning.

Clause 30.0 **COLD BEND TEST OF COMPLETE WIRE**

Test Method: UL Subject 4703

Requirements: No cracking or splitting.

Procedure: Samples of complete wire shall be conditioned for 4 hours at -40°C. Following the conditioning period and while still in the conditioning cabinet, the wire is then wound tightly for six complete turns around a mandrel at a rate of one rotation every 3 seconds. The wire is then visually examined for evidence of any cracking or splitting.

8.0 Revision History

Issue No.	Amendment No.	CR No.	Date	Incorporated By
2		CR08-DP-265	07/08/2008	Antonio Pagliuca
3		CR09-DP-033	03/03/2009	Antonio Pagliuca
4		CR09-DP-083	11/05/2009	Antonio Pagliuca

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