OULUN AMMATTIKORKEAKOULU

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ELEVATOR SHAFT LIGHTING OPTIMIZATION

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Tämän opinnäytetyön tarkoituksena oli selvittää LED- valaisimien kustannus- ja elinikäkaaren eroja verrattuna ominaisuuksiltaan vastaavanlaisiin halogeenivalaisimiin, LED- valaisimien sähköistyksen toteuttamista, sähköisten raja-arvojen määrittelyä ja testaamista. Tavoitteena oli suunnitella sekä luoda testituloksien ja vaatimusten perusteella vastaava uuden sukupolven hisseihin soveltuva kuiluvalaistus.

Opinnäytetyö toteutettiin tutkimuksena, jossa eri valmistajien LED-valonauhoille tehtiin eristysvastusmittaus, kytkentäsysäysvirtamittaus, mekaaninen repeytymistesti, mekaaninen taivutustesti sekä ympäristötesti. Opinnäytetyössä käsitellään myös valaistukseen liittyvää perustermistöä. Testien tavoitteena oli varmistaa, että uudet LED- valonauhat soveltuvat korvaamaan käytössä olevat halogeenivalaisimet ja noudattavat uuden hissistandardin EN 81-20 asetettuja vaatimuksia.

Opinnäytetyötä varten laadittiin testisuunnitelmia sekä aikataulu, jonka puitteissa toteutettiin vaadittavat testaukset, laadittiin valaisinten hyväksymiskriteerit sekä luotiin vaatimusmäärittely testituloksien ja standardin EN 81-20 perusteella. Uuden standardin myötä hissikuilun valaistusvoimakkuuden minimiarvon tulee olla hissikuilussa yhden metrin etäisyydeltä mitattuna vähintään 20 luksia. Konehuoneen työskentelyalueella vaaditaan vähintään 200 luksia yhden metrin etäisyydeltä mitattuna työskentelytasosta.

Opinnäytetyö tehtiin asiakkaan toiveiden mukaisesti. Valaisimiksi valikoitui sekä Weco- että Elcart- merkkiset LED- nauhat, jotka molemmat läpäisivät niille annetut kriteerit EN 81-20 standardin ja asiakkaan vaatimusten mukaisesti. Opinnäytetyön lopuksi käytiin läpi valmistajien elinkaarikustannuksia vertaamalla niitä halogeenivalaisimiin. Tutkimus osoitti, että uudet LED-valaisimet ovat huomattavasti kustannustehokkaampia, energiaystävällisempiä, kestävämpiä ja huoltovapaampia kuin halogeenivalaisimet

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Asiasanat: Halogen lamp, Fluorescent light, LED strip, EN 81-20, Light efficiency test, Insulation resistance test, Inrush current test, Cost evaluation, Weco, Crosspoint, Elcart

ABSTRACT

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The purpose of this thesis was to find out the differences in the cost and life cycle of LED luminaires compared to halogen luminaires with similar characteristics, the implementation of LED luminaire electrification, the definition of electronic limit values and the specification of requirements with the JAMA tool. The aim was to design and create a similar solution for shaft lighting suitable for the new generation of elevators based on the test results and requirements.

The thesis was carried out as a study, in which insulation resistance measurement, switching impulse current measurement, mechanical tear test, mechanical bending test and environmental test were performed on LED light strips of different manufacturers. The thesis also deals with basic terminology related to lighting. The aim of the tests was to ensure that the new LED light strips are suitable to replace the halogen luminaires in use and to comply with the requirements of the new elevator standard EN 81-20.

For the thesis, test plans and a schedule were prepared, within which the required tests were carried out, acceptance criteria for luminaires were drawn up, and a specification of requirements was created on the basis of the test results and the standard EN81-20. Based on the research, a new LED luminaire could be put into production. With the new standard, the minimum value of the illuminance of the elevator shaft must be at least 20 lux measured in the elevator shaft from a distance of one meter. In the engine room area, a minimum of 200 lux measured at a distance of one meter in the work area is required.

The thesis was done according to the client's wishes. Both Weco and Elcart LED strips were selected as luminaires, both of which passed the criteria given to them in accordance with the EN 81-20 standard and customer requirements.

At the end of the thesis, the life cycle costs of the manufacturers are reviewed by comparing them with halogen luminaires. The study show that the new LED luminaires are significantly more cost-effective, energy-efficient, durable and maintenance-free than halogen luminaires.

ACKNOWLEDGEMENTS

I would like to thank KONE Corporation for an interesting thesis topic that allowed me to familiarize myself with the different types of luminaires, their technical capabilities, and production solutions and also allowed me to have an influence on KONE solutions in such a deep level which was completely new to me.

Special thanks to Tapani Talonen and Olli Mikkola from KONE and Esa Pakonen, the supervising teacher of this thesis.

Oulu, Finland

Henri Lackman

CONTENTS

1 INTRODUCTORY

The use of halogen luminaires in modern elevators has remained an old-fashioned way due to their service life, power consumption and limited solution capabilities. The new LED luminaires offer easier installation method, better power efficiency and service life. They are also compatible with the new EN 81-20 standard. The full potential of the LED lights can be achieved especially when they are used with bus technology or some other type of controllable solution.

This thesis' main objective was to find out about different elevator lighting solutions and capability of the LED lamps compared to the old halogen type of lights used currently. The LED lights used in the KONE elevators are mostly designed to be used in spaces where they are exposed to various temperature and moisture changes.

1.1 KONE Corporation

KONE Corporation is an elevator company whose history begins from the year 1910 in Helsinki. From there until today it has achieved its position as one of the leading elevator manufacturers in the world. Their mission is to improve the flow of the urban life. KONE provides elevators, escalators and automatic building doors for various buildings around the world. (1.)

1.2 Meaning of the LED light reform for the elevator

The new LED light concept in elevators has been defined by the new upcoming standard EN 81-20 which includes requirements for the next generation elevators. The minimum measured lumen value in elevator shaft area has to be at least 20 lux in any area inside the elevator shaft and 200 lux in the machinery area.

When considering new lighting solution for the next generation elevators and knowing the supposed purpose and environment for the light considering the old lighting solution it was necessary to define and test the new LED lighting solution. Another reason to update the current solution is cost evaluation for which the solution would have more suitable features such as low production cost and longer lifetime expectancy.

LED lights have also proven to be more maintenance-free and easier to install due to their structural design. Since the main lighted areas will be the shaft and machinery area, the focus can be more on functionality and reliability rather than looks and design. (2.)

2 STANDARDS AND MAINTENANCE

Standardization can be defined as: ”creating agreed ways of doing something”. Standards are norms and models which are defined to help and guide public authorities, consumers, and industry. Standards help by increasing product compatibility and safety for consumers and it also protects the environment. It is also a very good tool to simplify domestic and international trade between different countries. Standards are published as documents so that they can be obtained and used by everyone. The exploitation and use of the standards are free. (3.)

In the earlier standard, the required lux intensity above the elevator car roof working area was minimum of 50 lux and at least 50 lux above elevator shaft base. In the elevator shaft and other areas excluding the shadow areas caused by the elevator car and its parts, the minimum lux was not mentioned. The new EN 81-20 contains the next generation lighting standard. The main reform of the standard is to have better elevator and shaft lighting by changing the wanted intensity requirements for the lamps. The new standard EN 81-20 requires the following set of values regarding the new elevator concepts. (2.)

In the elevator machinery area:

- At least 200 lux in the elevator machinery working areas and at least 50 lux on the elevator car roof level to move between working areas.
- In emergency situations at least 5 lux for one hour.
- At least 100 lux on the elevator car control devices and measured above the elevator car floor level one meter above.

In the elevator shaft area:

- At least 50 lux measured one meter above the elevator car roof.
- At least 50 lux measured one meter above the elevator shaft pit in all those areas where a worker can stand, move and work.
- At least 20 lux in other areas, not regarding elevator shaft or its parts that can cause shadow areas. (4.) (5.)

3 CONSEPT OF LIGHT

Light is an electromagnetic radiation detected by human eye in natural conditions. FIGURE 1 shows the visible wavelengths of light which are from 400 nm up to 780 nm measured in natural conditions. This spectrum is known as visible spectrum between Ultraviolet spectrum (100 nm to 400 nm) and Infrared spectrum (780 nm up to 1 000 000 nm). (6.)

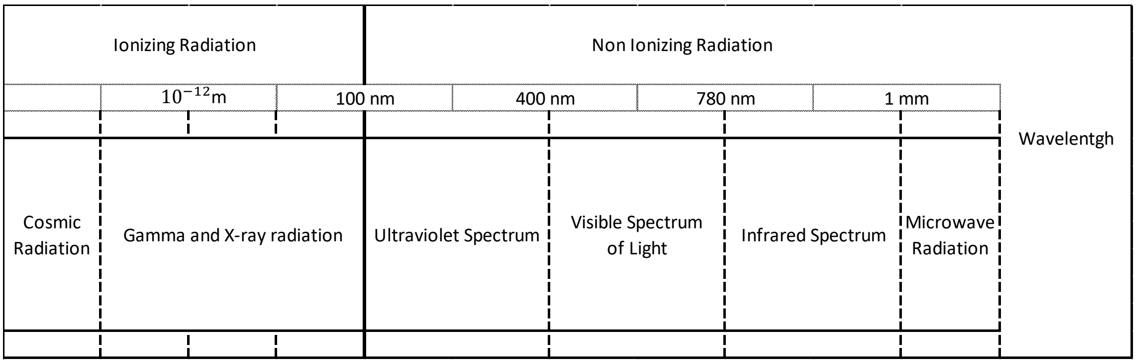


FIGURE 1: Visible spectrum detected by human eye. (6.)

3.1 Amount of light, Lumen Φ

The amount of light, also known as luminous flux, is measured by using the indicator lumen (lm). The higher the value of lumen the brighter the light to put it simple. Lumen is an important factor showing us how powerfully the lamp is able to transform energy into light. This can be called lumen to watt ratio (lm / W). Because LED diodes consume less power, this factor is higher than compared to other lamp types. (7.)

3.2 Intensity of light, Lux

Another type of factor to show the amount of light is lux (lx). Lux describes the amount of light hitting a measured surface. Lux is one of the factors describing the quality of the lighting. One lux is one lumen measured in one square meter area (lm / m2). It is important to take notice from which angle the light is hitting the surface. Factors affecting the lux value are the light source’s lumen value, distance from the measured surface and the optical features of the light. (8.)

3.3 Brightness, I

Brightness describes the amount of light leaving the source of light in some specific direction. Brightness helps to establish and indicate the light's distribution curve. The factor of the brightness is known as candela (cd). (9.)

3.4 Luminance, L

Luminance describes the density of light reflecting from a surface. The unit describing the luminance reflecting from the surface is candela per one square meter (cd / m2). An object gets brighter when the luminance of its surface gets higher. If the luminance is not on the correct level, it can stress the eyes and make them weary. On the other hand, if the level of luminance is too high, the reflection is too bright. That is why it is important to set up the correct level of luminance so that too low level of it won't effect on your visual comfort and too high level of luminance won't cause too bright reflection on the surface. (13.)

3.5 Light efficiency, η

Light efficiency describes the amount of power light source will need to provide steady beam of light measured in values lux (lx). The light efficiency is known as lumen per watt (lm / W). (16.)

3.6 Color temperature, K

Color temperature will tell the tone of the color on Kelvin scale. The scale is from 2700 K – 6500 K which categorizes different colors to either warm (2700 K – 3300 K), neutral (3300 K – 5300 K) or cold (> 5300 K) shades based on the given Kelvin value. (13.)

4 STRUCTURE OF THE LAMPS / LAMP TYPES

The new elevator shaft lights differ from the old ones as they use LEDs to emit light instead of fluorescent type of halogen lights. This paragraph explains the basic principle of the functionality of LEDs.

4.1 LED light

The abbreviation of LED comes from the words Light Emitting Diode. LED components are semi conductive components which converts electric energy to light. Diode is usually a two-terminal crystal which has a p-side and a n-side. The n-side contains extra electrons and the p-side contains holes in the crystal allowing electrons to be attached on. In this way, the diode passes electrons from n-side to p-side which produces light and heat. This is called emission.

The LED lamps contain two main parts: the LED component and the ballast machine. LED is a diode which passes electric current to only one direction. For this reason LEDs require a DC voltage instead of AC voltage which would cause LEDs to dim due to the frequency. In Europe the frequency is 50 Hz. The ballast converts AC voltage to DC voltage. The advantages of the LED lamps compared to the fluorescent type of lamps are lower heat reduction, longer lifespan, better controllability and its overall accessibility on modern day solutions. (9.)

5 COMMERCIAL LED STRIP LIGHTS

As a global company, it is crucial to have alternative component suppliers to maintain easy delivery for the LED strip lights. The three selected suppliers for the solution were Weco, Crosspoint and Elcart. The acceptance criteria are defined by the standards and KONE solution. For this reason the manufacturing, safety and standards point of view of these different LED lights need to have equal technical capabilities and passing standards to be selected as an alternative option.

5.1 WECO LED FLEX 05.BN6

Weco manufacturer provides a strip that is made of FPC (Flexible Printed Circuit Board). It produces high brightness lighting effect. It is flexible and its built-in properties make it also easy to install and maintain on the working site. The protection level of the Weco has been classified as IP65. Additional information and technical specification can be found in FIGURE 2. (11.)

Specifications

Model No.	Diodes/m	Section Cut	Max. Length	Material Coating	Cable Type
05.BN6	120	1m	100m	PVC Flame retardant	$H03VVH_2$-F 2 x 0.75mm^2
Input Voltage	Max. Current	Power/m	Lumens	Working Temperature	IP Rating
230VAC±10%, 50/60Hz	4A	7.5W	600lm	-10°C to +40°C	IP65
Lifetime	Light Colour	LED Model	Beam Angle	Weight (without cable)	Dimensions
50,000 hours	6500K±8%	SMD2835	120°	115g/m	15 x 7mm

FIGURE 2: Weco LED FLEX 05.BN6 technical specifications. (11.)

Weco manufacturer provides a LED strip which contains 120 diodes per 1 meter length. The maximum allowed working length for the strip is 100 meters and it is delivered in a 50 meter reel. The Weco LED strip is made of PVC, flame retardant material with IP rating 65. It provides a steady 600 lm brightness. Light color is 6500K + / - 8 %. Lifespan for the LEDs is 50000 hours (see FIGURES 2, 3). (11.)

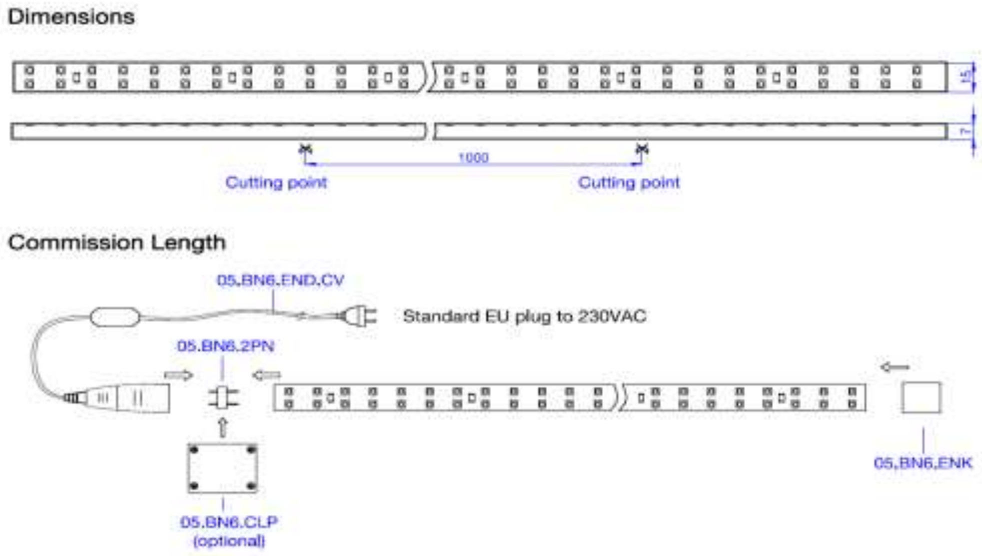
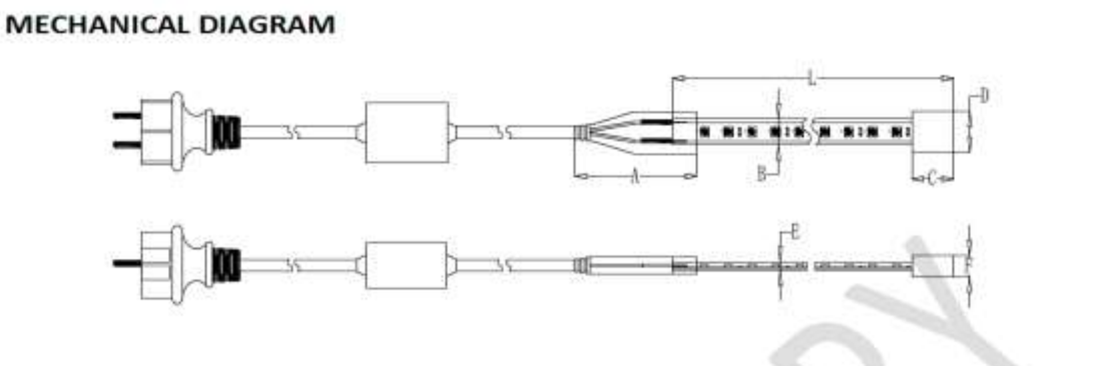


FIGURE 3: Weco LED FLEX 05.BN6 length. (11.)

5.2 Crosspoint

Crosspoint LED strip is made of FPC (Flexible Printed Circuit Board). It produces a high-brightness lighting effect around 5700 K – 6500 K color temperature. The strip contains 60 diodes per 1 meter length and it is delivered in a 20 meter reel. The maximum bending diameter for the strip is 6 cm. This makes it resistant to shocks caused by the environment. Its flexibility and properties make it also easy to install and maintain on-site. The protection level of the Crosspoint has been classified as IP44, with double PVC plastic insulation. Additional information and technical specification can be found from the FIGURE 4 and FIGURE 5. (18.)



A	B	C	D	E	F	L
60±0.5mm	11.3±0.3mm	20±0.5mm	15±0.5mm	7.5±0.2mm	11.5±0.5mm	20m ±10cm

FIGURE 4: Crosspoint mechanical assembly. (18.)

MODEL:	ROPE LIGHT 20m length	
ELECTRICAL SPECIFICATION	OPERATING VOLTAGE	220-240VAC
	FREQUENCY RANGE	50/60HZ
	OPERATING CURRENT	0,03 A/m
	RATED POWER	6,5 W/m
	SUPPLY CABLE	1,5m, 2x0.75mm2 with EU plug
PROTECTION	WATERPROOF	IP44
LUMINOUS SPECIFICATION	LED TYPE	Top LED 2835
	LED PITCH	16.5mm
	LUMINOUS FLUX	615 lm/m +/-10%
	COLOR	White 5700K ~ 6500K
	CRI (RA)	>=80
	BEAM ANGLE	120°
	LIFE TIME	50.000 hours
ENVIRONMENT	STORAGE TEMPERATURE	0°C ~ +60°C
	WORKING TEMPERATURE	-10°C ~ +45°C
	WORKING HUMIDITY	40% ~ 70% RH
OTHERS	STRIPLED LENGTH	20m
	STRIPLED BODY	11.3x7.5mm
	NET WEIGHT	2500g
	GROSS WEIGHT	3200g

FIGURE 5: Crosspoint technical specifications. (18.)

5.3 Elcart

Elcart provides a similar type of LED strip. It has IP65 rating with 900 lm brightness and 180 diodes per 1 meter length. Color temperature of the diodes is 6000 K – 7000 K. It consumes 13 W per meter with 230 VAC input voltage. It has IP65 rating when using an additional plastic extension piece installed directly on to the power cable connector plug. This will make the connection as IP65 certified (see FIGURE 6). (17.)

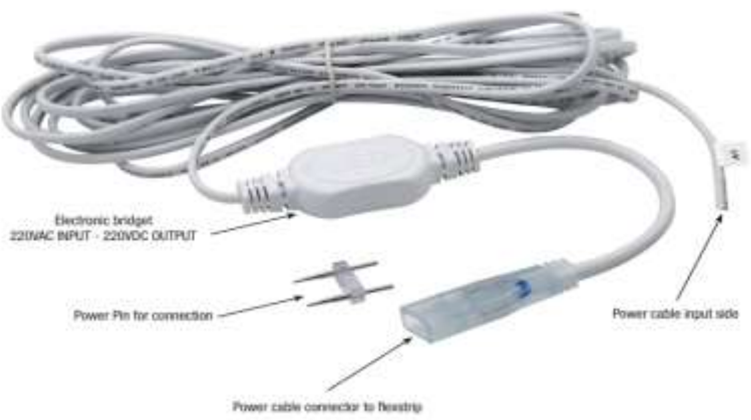


FIGURE 6: Elcart mechanical assembly. (17.)

6 COMPONENTS AND INSTALLATION

In case of installing LED strips a specific type of installation brackets need to be used. These brackets are provided by company Giovenzana. The function of these devices is to help install the LED strips easily and lower the time needed for installation and maintenance in the future.

It was also discovered that some manufacturers LED strips do not necessarily hold up certain IP protection class for moisture so for those cases specific silicone glue has to be added in the connection point of the LED strip. This helps to keep the moisture out from the connecting pins and helps to endure the necessary functions in the harshest conditions IP65 class. (12.)

6.1 Attachment bracket

The LED strips are attached to the outside wall inside the elevator shaft by specific attachment brackets. The LED strip goes through these brackets' little holes which then lock the strip to be unable to slide off (see FIGURE 7). (12.)

FIGURE 7: Attachment bracket. (12.)

6.2 Silicone glue

Silicone glue is used for maintaining the correct insulation between the LED strip and its connector. The issue in the connector’s seal does make it exposed to moisture so extra silicone needs to be applied inside the seal.

Silicone needs to be retained in a dry place in 20 °C temperature to be sure it maintains its sealing properties. Also direct sunlight needs to be avoided so that the plastic seal does not become brittle (see FIGURE 8). (12.)

FIGURE 8: Silicone glue and LED strips seal. (12.)

7 LIGHT EFFICIENCY TEST

Light efficiency test was performed to find better lighting solutions in terms of light intensity and to guarantee that the new EN 81-20 standard regulations met with the selected manufacturer samples. Evaluation between different manufacturers LED strips was done by comparing the shaft lighting between the new LED strip concept, LED shaft lights currently in use, and the old fluorescent (halogen type of) lights.

The meaning for this test was to find out whether we can use the new LED strips to illuminate the needed construction/working area with a needed intensity. The tested area was measured to be 3500 mm X 3500 mm size area and the test was carried out from one meter distance from the illuminated surface. (14.)

7.1 Acceptance criteria

According to the new EN 81-20 standard the minimum acceptable lux value measured in the working area is needed to be at least 20 lux in the shaft area and at least 200 lux in the machinery area for the safety of the workers. These are defined in their categories in the standard EN 81-20. (4.) (5.)

7.1.1 Acceptance criteria for the elevator shaft area

The shaft shall be provided with permanently installed electric lighting, giving the following intensity of illumination, even when all doors are closed, at any position of the car throughout its travel in the shaft:

- At least 50 lux, 1,0 m above the car roof within its vertical projection
- At least 50 lux, 1,0 m above the pit floor everywhere a person can stand, work and/or move between the working areas;
- At least 20 lux outside of the locations defined in a) and b).

The new LED strips must be able to achieve the same required minimum values according to the new EN 81-20 standard to replace the old fluorescent type of lights in the same kind of environments and working areas. (4.)

7.1.2 Acceptance criteria for the elevator machinery area

Machinery spaces and pulley rooms shall be provided with permanently installed electric lighting:

- With an intensity of at least 200 lux at the elevator car floor level everywhere a person needs to work and 50 lux at floor level when moving between working areas.
- Move between working areas. The supply for this lighting shall be in conformity with EN 81-20 5.10.7.1. (5.)

The light efficiency test for the machinery area was simulated and measured inside of the black box to ensure minimum light disturbance from the outside. The DUT (Device Under Test) needed to reach at least a minimum of 170 lux in all measurement points considering the divergence value of 30 lux because of the decision of using the black box. The test needed to be done in-side of the black box to demonstrate the darkest conditions. (14.)

7.2 Test plan and equipment specifications

Dimensions of the black box were given to be: width = 3500 mm x height = 3300 mm x depth = 3500 mm. The area was constructed by a small grid measured to be by width = 500 mm x height = 500 mm x depth = 500 mm (see FIGURE 9). (14.)

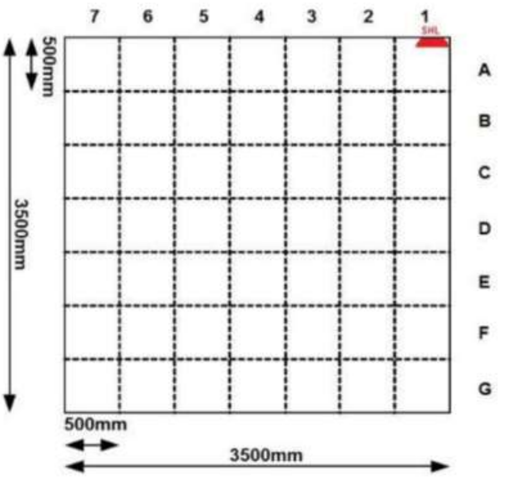


FIGURE 9: Measuring area for the shaft light. (14.)

The testing was performed and measured inside the black box room in laboratory conditions. The least efficient case would be to install the lamps in the farthest corners of the shaft area. Knowing this the DUT was installed in the most distant corner for maximizing the effect when installing lights not efficiently. Each of the tests was performed by placing lux meter on the center of the floor and orienting it towards the light source (see FIGURE 10). (14.)

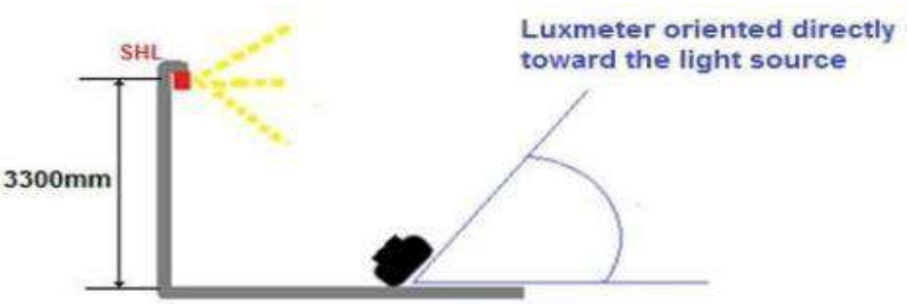


FIGURE 10: Lux meter orientation. (14.)

FIGURE 11 shows the light intensity testing area in the machinery area. Each test was performed placing the lux meter in the middle of a 500 mm x 500 mm grid where it was oriented towards the center of the light source. The machinery area needs minimum of at least 200 lux measured in any testing grid from A to F. (14.)

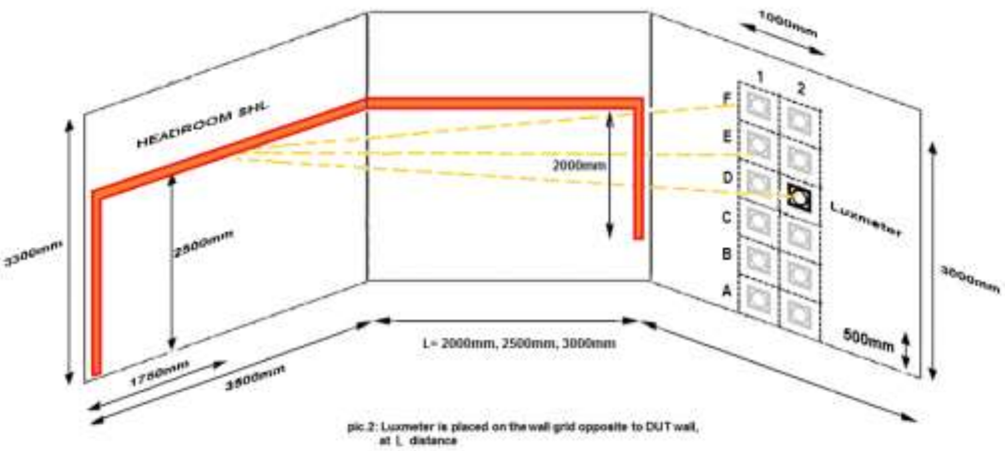


FIGURE 11: Testing grid for the simulated test in machinery area A, B, C, D, E, F (1, 2) (14.)

The light efficient tests were carried out as follows:

- Step 1: Measuring the first and last LED strip samples at nominal voltage
- Step 2: Measuring at +10 % and -15 % of nominal voltage power supply
- Step 3: Measuring the first and last LED strip of the 50 meter LED strip samples at nominal voltage. (14.)

7.2.1 Specific requirements for a device under test (DUT) and test plan

To make sure that the light efficiency can be measured correctly the DUT's needed to be cut in a certain length to ensure the right test conditions for the samples. This was needed for a comparison of the fluorescent type of lights. (14.)

For efficiency light test in the Shaft area with nominal voltage:

- ELCART LED Strip 50 meter length
- WECO LED Strip 50 meter length
- CROSSPOINT LED Strip 50 meter length

For efficiency light test in the Shaft area with +10 % and -15 % of nominal voltage:

- ELCART LED Strip 3 meter length
- WECO LED Strip 3 meter length
- CROSSPOINT LED Strip 3 meter length

For efficiency light test in the Machinery area:

- ELCART LED Strip 10 meter length
- WECO LED Strip 10 meter length
- CROSSPOINT LED Strip 10 meter length. (14.)

The test results are shown in the table marked by different colors to describe lighting intensity (see TABLE 1):

TABLE 1: Color coding during the test results is shown in table. (14.)

≥200 lux
≥100 <200 lux
≥50 <100 lux
≥20 <50 lux
<20 lux

7.3 Light efficiency test results: Elcart

This paragraph contains test results for the Elcart test sample. Three different test samples were provided for the testing.

- Test sample 1: Elcart LED Strip 50 meters length with nominal voltage
- Test sample 2: Elcart LED Strip 3 meters length with +10 % and -15 % of nominal voltage
- Test sample 3: Elcart LED Strip 10 meters length. (14.)

7.3.1 Elcart – First and last 3 meters of strip with nominal voltage

Test sample 1 was tested first 3 meters of the Elcart LED strip with nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for the LED strip quality reasons (see TABLE 2). (14.)

TABLE 2: Elcart LED strip 50 meter length – First 3 meters. (14.)

Elcart LED strip – 50 meter - First 3 meters								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	35	45	61	87	135	266	381	[lux]
B	37	50	60	87	129	201	260	[lux]
C	40	47	60	79	101	133	144	[lux]
D	38	43	54	67	80	94	96	[lux]
E	35	37	47	54	62	71	71	[lux]
F	32	32	41	45	50	52	54	[lux]
G	30	30	35	38	43	45	43	[lux]

Test sample 1 was also tested with the last 3 meters of the same LED strip with nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 3). (14.)

TABLE 3: Elcart LED strip 50 meter length – Last 3 meters. (14.)

Elcart LED strip – 50 meter - Last 3 meters								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	46	55	77	106	155	276	402	[lux]
B	46	57	78	98	149	185	217	[lux]
C	43	52	69	85	116	125	121	[lux]
D	40	48	59	70	88	88	84	[lux]
E	35	43	50	58	65	67	64	[lux]
F	33	37	43	45	52	50	47	[lux]
G	30	32	35	40	42	41	37	[lux]

7.3.2 Elcart – First and last 3 meters of strip with + 10 % and - 15 % nominal voltage

Test sample 2 was tested first 3 meters of the Elcart LED strip with +10 % of the nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 4). (14.)

TABLE 4: Elcart LED strip 50 meter length – First 3 meters with +10 % of nominal voltage. (14.)

Elcart LED strip +10% of Nominal Voltage (242 V) – First 3 meters								
Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	56						883	[lux]
B								[lux]
C			89		160			[lux]
D				91				[lux]
E			66		88			[lux]
F								[lux]
G	33						51	[lux]

Test sample 2 was also tested with the last 3 meters of the same LED strip with -15 % of the nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 5). (14.)

TABLE 5: Elcart LED strip 50 meter length – Last 3 meters with -15 % of nominal voltage. (14.)

Elcart LED strip -15% of Nominal Voltage (187 V) – Last 3 meters Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	27						356	[lux]
B								[lux]
C			43		65			[lux]
D				42				[lux]
E			34		40			[lux]
F								[lux]
G	21						26	[lux]

7.3.3 Elcart – Machinery area light efficiency test results

Test sample 3 was tested in the machinery area with wall to wall distance. Test results will state if the LED strip can provide enough light for the machinery working area where the minimum lux value regarding the new standard has to be at least 200 lux (see TABLES 6, 7, 8). (14.)

TABLE 6: Elcart LED strip 10 meter length (wall to wall distance = 2000 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (2000 mm x 3500 mm)			
	1	2	
F	267	204	[lux]
E	306	228	[lux]
D	293	251	[lux]
C	266	208	[lux]

TABLE 7: Elcart LED strip 10 meter length (wall to wall distance = 2500 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (2500 mm x 3500 mm)			
	1	2	
F	211	204	[lux]
E	254	212	[lux]
D	238	217	[lux]
C	225	207	[lux]

Table 8: Elcart LED strip 10 meter length (wall to wall distance = 3000 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (3000 mm x 3500 mm)			
	1	2	
F	240	201	[lux]
E	252	207	[lux]
D	249	204	[lux]
C	243	188	[lux]

7.4 Light efficiency test results: Weco

This paragraph contains test results for the Weco test sample. For the testing three different test samples were provided.

- Test sample 1: Weco LED Strip 50 meters length with nominal voltage
- Test sample 2: Weco LED Strip 3 meters length with +10 % and -15 % of nominal voltage
- Test sample 3: Weco LED Strip 10 meters length. (14.)

7.4.1 Weco – First and last 3 meters of strip with nominal voltage

Test sample 1 was tested first 3 meters of the Weco LED strip with nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for the LED strip quality reasons (see TABLE 9). (14.)

TABLE 9: Weco LED strip 50 meter length – First 3 meters. (14.)

Weco LED strip – 50 meter - First 3 meters								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	46	58	75	100	170	356	771	[lux]
B	49	61	81	133	165	252	285	[lux]
C	49	58	75	99	131	172	161	[lux]
D	45	53	65	67	102	114	108	[lux]
E	43	49	57	68	77	81	80	[lux]
F	40	42	47	54	62	63	63	[lux]
G	30	35	40	45	49	52	50	[lux]

Test sample 1 was also tested with the last 3 meters of the same LED strip with nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 10). (14.)

TABLE 10: Weco LED strip 50 meter length – Last 3 meters. (14.)

Weco LED strip – 50 meter - Last 3 meters								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	49	62	81	109	164	301	649	[lux]
B	51	64	79	110	147	220	284	[lux]
C	50	60	75	93	120	143	141	[lux]
D	47	56	67	79	91	98	96	[lux]
E	43	49	57	64	70	73	71	[lux]
F	39	41	47	52	54	53	50	[lux]
G	30	33	38	43	43	43	41	[lux]

7.4.2 Weco – First and last 3 meters of strip with +10 % and -15 % of nominal voltage

Test sample 2 was tested first 3 meters of the Weco LED strip with +10 % of the nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 11). (14.)

TABLE 11: Weco LED strip 3 meter length with +10% of nominal voltage. (14.)

Weco LED strip +10% of Nominal Voltage (242 V) – 3 meters Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	51						751	[lux]
B								[lux]
C			89		150			[lux]
D				85				[lux]
E			64		88			[lux]
F								[lux]
G	34						45	[lux]

Test sample 2 was also tested with the last 3 meters of the same LED strip with -15 % of the nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 12). (14.)

TABLE 12: Weco LED strip 3 meter length with -15 % of nominal voltage. (14.)

Weco LED strip -15 % of Nominal Voltage (187 V) – 3 meters								
Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	33						471	[lux]
B								[lux]
C			51		94			[lux]
D				52				[lux]
E			38		54			[lux]
F								[lux]
G	22						29	[lux]

7.4.3 Weco – Machinery area light efficiency test results

Test sample 3 was tested in the machinery area with wall to wall distance. Test results will state if the LED strip can provide enough light for the machinery working area where the minimum lux value regarding the new standard has to be at least 200 lux (see TABLES 13, 14, 15). (14.)

TABLE 13: Weco strip 10 meter length (wall to wall distance = 2000 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (2000 mm x 3500 mm)			
	1	2	
F	224	202	[lux]
E	286	257	[lux]
D	256	246	[lux]
C	275	224	[lux]

TABLE 14: Weco strip 10 meter length (wall to wall distance = 2500 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (2500 mm x 3500 mm)			
	1	2	
F	207	192	[lux]
E	258	219	[lux]
D	269	222	[lux]
C	253	205	[lux]

TABLE 15: Weco strip 10 meter length (wall to wall distance = 3000 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (3000 mm x 3500 mm)			
	1	2	
F	210	192	[lux]
E	221	206	[lux]
D	242	207	[lux]
C	239	194	[lux]

7.5 Light efficiency test results: Crosspoint

This paragraph contains test results for the Crosspoint test sample. For the testing three different test samples were provided.

- Test sample 1: Crosspoint LED Strip 50 meters length with nominal voltage
- Test sample 2: Crosspoint LED Strip 3 meters length with +10 % and -15 % of nominal voltage
- Test sample 3: Crosspoint LED Strip 10 meters length. (14.)

7.5.1 Crosspoint – First and last 3 meters of strip with nominal voltage

Test sample 1 was tested first 3 meters of the Crosspoint LED strip with nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 16). (14.)

TABLE 16: Crosspoint LED strip 50 meter length – First 3 meters. (14.)

Crosspoint LED strip – 50 meter - First 3 meters								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	37	45	35	83	137	262	380	[lux]
B	40	51	66	87	136	190	239	[lux]
C	40	50	62	78	107	126	131	[lux]
D	37	46	56	66	81	82	87	[lux]
E	34	41	63	54	60	62	65	[lux]
F	30	36	46	44	48	48	45	[lux]
G	26	31	39	38	39	39	37	[lux]

Test sample 1 was also tested with the last 3 meters of the same LED strip with nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 17). (14.)

TABLE 17: Crosspoint LED strip 50 meter length – Last 3 meters. (14.)

Crosspoint LED strip – 50 meter - Last 3 meters								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	28	37	46	63	97	174	506	[lux]
B	32	39	49	78	119	197	249	[lux]
C	34	42	55	73	81	123	145	[lux]
D	35	44	48	66	81	94	97	[lux]
E	34	39	44	54	65	71	80	[lux]
F	31	36	39	44	48	55	58	[lux]
G	25	29	32	36	40	44	43	[lux]

7.5.2 Crosspoint – First and last 3 meters with +10 % and -15 % of nominal voltage

Test sample 2 was tested first 3 meters of the Crosspoint LED strip with +10 % of the nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 18). (14.)

TABLE 18: Crosspoint LED strip 3 meter length with +10 % of nominal voltage. (14.)

Crosspoint rope light +10 % of Nominal Voltage (242 V) – 3 meters								
Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	43						536	[lux]
B								[lux]
C			64		99			[lux]
D				63				[lux]
E			49		59			[lux]
F								[lux]
G	28						34	[lux]

Test sample 2 was also tested with the last 3 meters of the same LED strip with -15 % of the nominal voltage. The length of the test sample was 50 meters during the testing. This would benefit the testing for LED strip quality reasons (see TABLE 19). (14.)

TABLE 19: Crosspoint LED strip 3 meter length with -15 % of nominal voltage. (14.)

Crosspoint rope light -15 % of Nominal Voltage (187 V) – 3 meters								
Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	27						436	[lux]
B								[lux]
C			41		72			[lux]
D				45				[lux]
E			32		43			[lux]
F								[lux]
G	19						21	[lux]

7.5.3 Crosspoint – Machinery area light efficiency test results

Test sample 3 was tested in the machinery area with wall to wall distance. Test results will state if the LED strip can provide enough light for the machinery working area where the minimum lux value regarding the new standard has to be at least 200 lux (see TABLE 20, 21, 22). (14.)

TABLE 20: Crosspoint LED strip 10 meter length (wall to wall distance = 2000 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (2000 mm x 3500 mm)			
	1	2	
F	196	183	[lux]
E	226	201	[lux]
D	217	198	[lux]
C	222	189	[lux]

TABLE 21: Crosspoint LED strip 10 meter length (wall to wall distance = 2500 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (2500 mm x 3500 mm)			
	1	2	
F	170	139	[lux]
E	192	173	[lux]
D	177	153	[lux]
C	165	136	[lux]

TABLE 22: Crosspoint LED strip 10 meter length (wall to wall distance = 3000 mm) (14.)

Machinery Area - 10 Meter			
Test 06/08/2019 (3000 mm x 3500 mm)			
	1	2	
F	147	114	[lux]
E	169	138	[lux]
D	159	135	[lux]
C	162	123	[lux]

7.6 Light efficiency test results: Voluntary damage

Test sample 3 was tested in the machinery area with wall to wall distance. Test results will state if the LED strip can provide enough light for the machinery working area where the minimum lux value regarding the new standard EN 81-20 has to be at least 170 lux measured in every grid to ensure sufficient lighting considering the mismatch possibility of 30 lux (see TABLES 23, 24, 25). (14.)

TABLE 23: Elcart LED strip 3 meter length – 1 meter damaged from the middle (14.)

Elcart LED strip – 3 meter sample – 1 meter damaged								
Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	28						365	[lux]
B								[lux]
C			42		72			[lux]
D				46				[lux]
E			33		41			[lux]
F								[lux]
G	21						27	[lux]

TABLE 24: Weco LED strip 3 meter length – 1 meter damaged from the middle (14.)

Weco LED strip – 3 meter sample – 1 meter damaged								
Test 02/10/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	40						644	[lux]
B								[lux]
C			53		93			[lux]
D				55				[lux]
E			44		54			[lux]
F								[lux]
G	21						29	[lux]

TABLE 25: Crosspoint LED strip 3 meter length – 1 meter damaged from the middle (14.)

Crosspoint rope light – 3 meter sample – 1 meter damaged								
Test 06/08/2019 (3500 mm x 3500 mm Black Room)								
	7	6	5	4	3	2	1	
A	24						378	[lux]
B								[lux]
C			36		65			[lux]
D				43				[lux]
E			33		38			[lux]
F								[lux]
G	21						25	[lux]

7.7 Lighting efficiency testing summary

Testing showed that the Crosspoint sample did not perform as expected. It did not pass the test with the same requirements given earlier in the testing. The sample did not illuminate enough for passing the minimum lux values given in the new EN 81-20 standard. Because of this discovery we could not use the Crosspoint as an alternative manufacturer anymore. Elcart and Weco samples did perform with the same level of requirements as the earlier halogen light. (14.)

8 MEASUREMENTS

This paragraph contains measurement results tested both in Hyvinkää reliability laboratory and Italy reliability laboratory. The test report was created by taking into account the EN 81-20 standard and the acceptance criteria defined by reliability laboratories and leading personnel responsible for the testing.

8.1 Test plan and testing in reliability laboratory

To be sure that these LED strips can be used in KONE solution some electrical, environmental, and light efficiency testing was needed to perform. Electrical and mechanical measurements were performed in Hyvinkää reliability laboratory. The mechanical and environmental testing was performed in KONE testing laboratory in Italy. (15.)

8.2 Inrush current test

Inrush current was measured from starting the DUT five times (5) in each mains voltage phase angle (90, 180, and 270) deg. DUT was decided to be a 1 x 50 meter sample with all three different manufacturers. The maximum inrush current values were then marked to the test results table. Maximum current drop distortion time was measured under 50 microseconds. (15.)

8.2.1 Acceptance criteria

The acceptance criteria for inrush current test is the maximum value of the inrush current which does not give tripping of the fuse or device malfunctioning while testing. Measured maximum inrush current peak must be in the limits of ETSI 300 132-3 graph (see FIGURE 12). The assumption for the LED lights was that the tripping current would be very mild. The reason for this assumption is that the LED itself is very energy efficient due to its given structure. (15.)

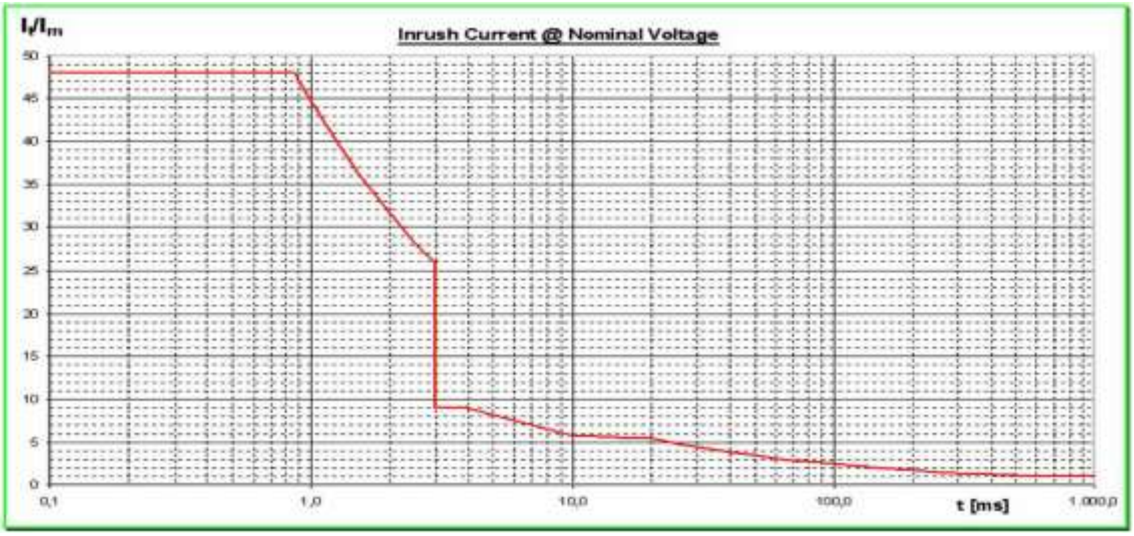


FIGURE 12: ETSI 300 132-3 graph (15.)

8.2.2 Test equipment specifications

The inrush current test required following test equipment. The description of the device is shown in FIGURE 13.

- AC power supply: Available short circuit current > 1 kA Isc (large enough not to limit the inrush current pulse)
- AC switch: Switch capable of connecting power to DUT in different AC voltage phase angles 90, 180 and 270 deg.
- EMC: Voltage dip tester is used for this purpose
- LISN: Line Impedance Stabilization Network L = 10 µH, R = 200 mΩ
- Load: DUT maximum load
- DUT: Device Under Test
- Oscilloscope: Capable of measuring the inrush current pulse and I2t value over shunt resistor R in LISN. (15.)

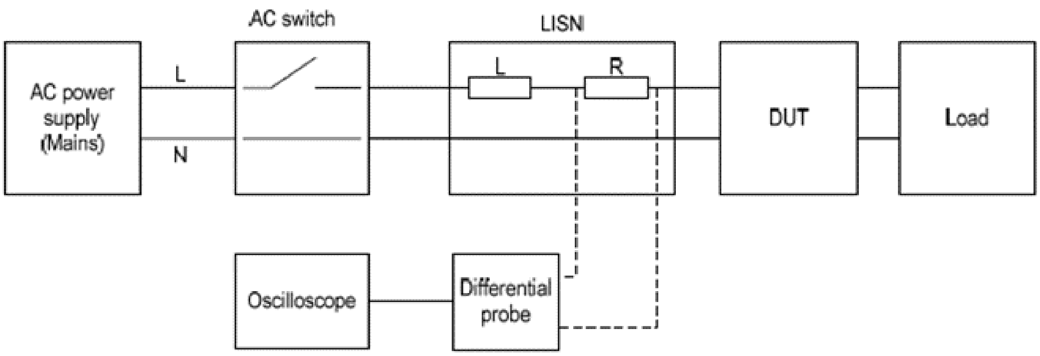


FIGURE 13: Block diagram of the inrush current measurement testing bench (15.)

8.2.3 Test results: Weco

The first tested LED strip was from manufacturer Weco. The first table shows the marked results given by inrush current measurement test (see TABLE 26). The maximum input current during the testing was 0.25 A. It is to be noted that the inrush current was measured in both 180 and 360 degrees phase angle. The inrush current measured in both cases would give roughly the same results as they are mirror results. (15.)

TABLE 26: Weco measured inrush current results (15.)

Weco LED FLEX 05.BN6					
Phase angle [deg.]	In-rush Max. [A]	Ratio Inrush current [A]/ Max input current [A]	In-rush High [A]	Ratio Inrush current [A]/ Max. Input current [A]	Pulse length [µs]
90 [deg]	1.01	4.04	1.01	4.04	≈ 10
180 [deg]	-	-	-	-	-
270 [deg]	0.88	3.52	0.88	3.52	≈ 10

The measured inrush current from Weco manufacturer’s LED strip showed us that the inrush current between balanced current and tripping current while startup was approximately 1.01 A in less than 50 microseconds. The results are very good for the purpose of the test (see FIGURE 14). (15.)

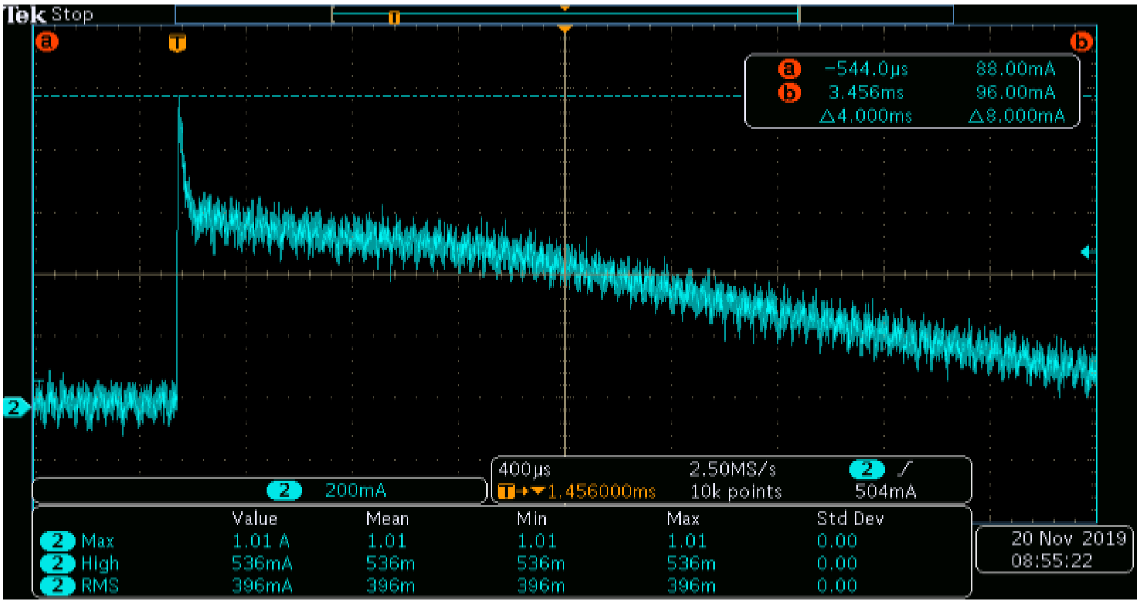


FIGURE 14: Inrush current phase angle 90 degrees Weco (15.)

The measured results in 270 degrees shows us “mirror” image and effect as in first picture with 90 degree phase angle. In this case the tripping current was about 0.88 A which is slightly less than the measured results in 90 degrees. The time to spike is approximately 50 microseconds (see FIGURE 15). (15.)

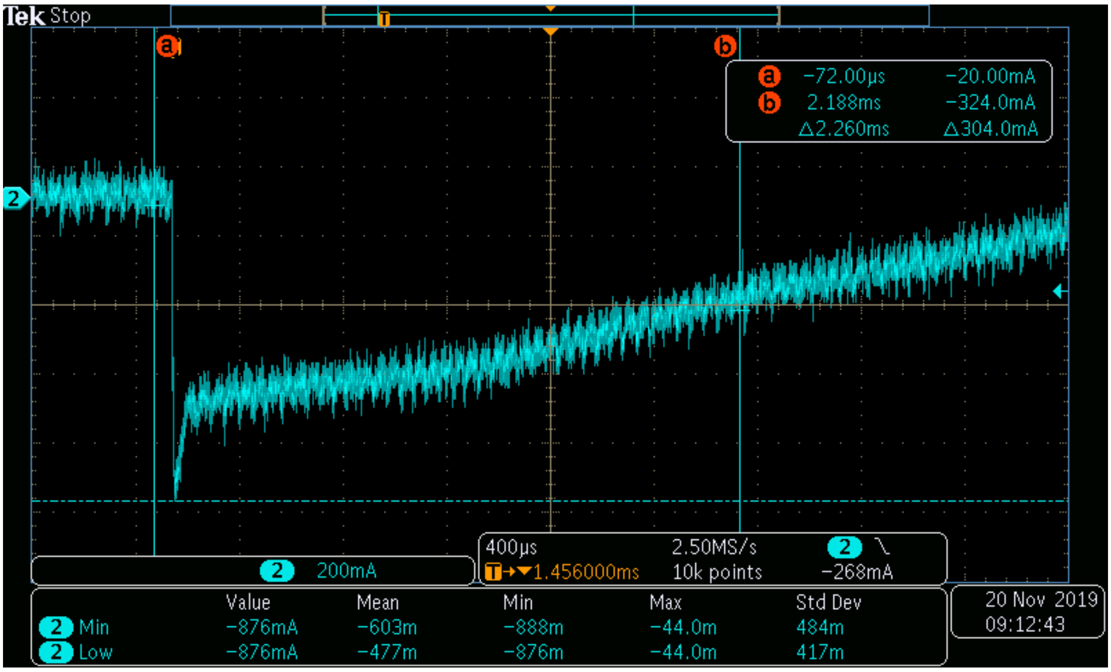


FIGURE 15: Inrush current phase angle 270 degrees Weco. (15.)

8.2.4 Test results: Elcart

The next LED strip to be tested was from manufacturer Elcart. TABLE 27 shows the marked results given by inrush current measurement test. The maximum input current during the testing was 0.3 A. It is to be noted that the inrush current was measured in both 180 and 360 degrees phase angle. (15.)

TABLE 27: Inrush current Elcart (15.)

Elcart LED FLEX 96/9986*					
Phase Angle [deg.]	In-rush Max. [A]	Ratio Inrush current [A]/ Max input current [A]	In-rush High [A]	Ratio Inrush current [A]/ Max. Input current [A]	Pulse length [µs]
90 [deg]	1.57	5.23	1.57	5.23	≈ 10
180 [deg]	-	-	-	-	-
270 [deg]	1.66	5.53	1.66	5.53	≈ 10

The measured inrush current from Elcart manufacturer's LED strip showed us that the inrush current between balanced current and tripping current while startup was approximately 1.66 A in less than 50 microseconds. The results are good enough for the purpose of the test (see FIGURE 16). (15.)

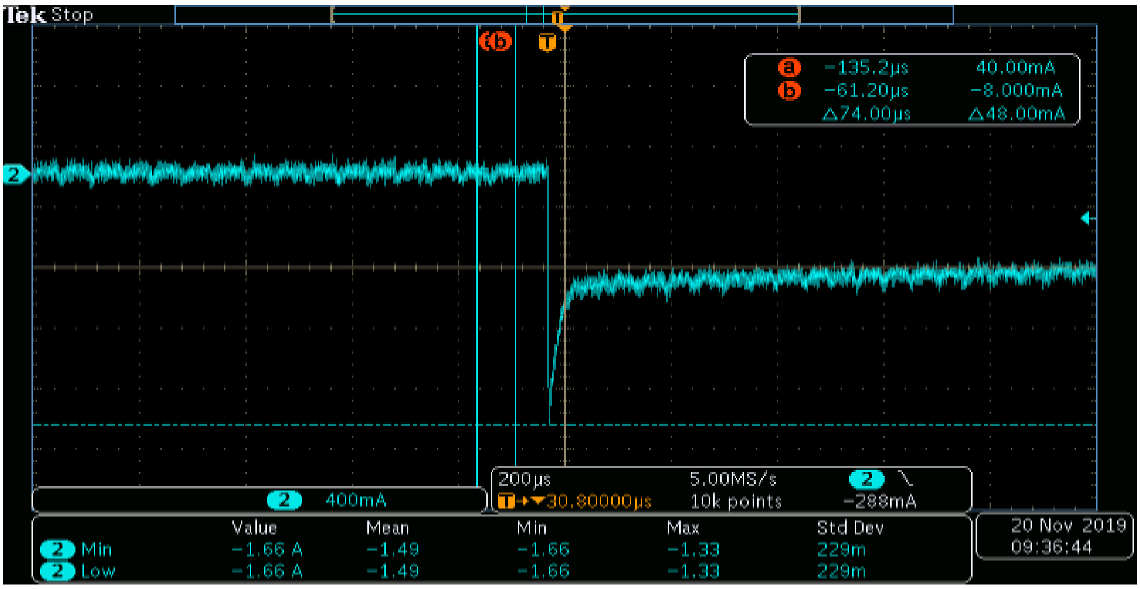


FIGURE 16: Inrush current phase angle 90 degrees Elcart (15.)

The measured results in 270 degrees shows us “mirror” image and effect as in first picture with 90 degree phase angle. In this case the tripping current was about 1.57 A which is slightly less than the measured results in 90 degrees. The time to spike is approximately 50 microseconds (see FIGURE 17). (15.)

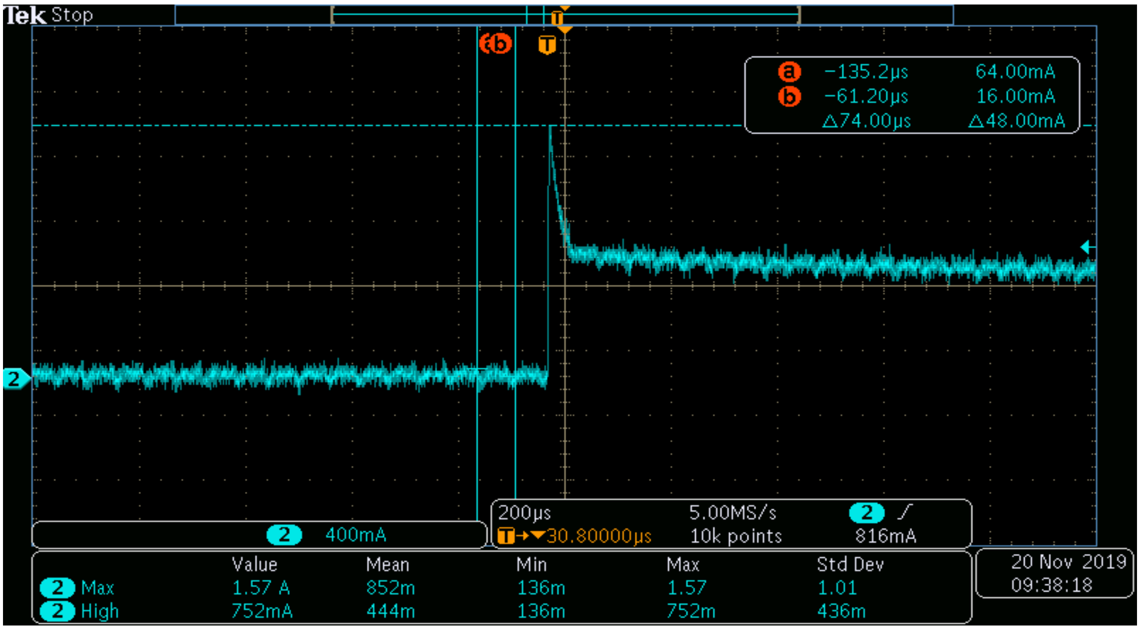


FIGURE 17: Inrush current phase angle 270 degrees Elcart (15.)

The third measurement was done with a 360 degree phase angle. This was done to demonstrate the earlier results. The assumption for the test results with 180 or 360 degree phase angle was that there would be no tripping current or it would not last very long is caused by the high capacitance the LED driver has. This makes the inrush current appear very high but would only last couple of microseconds. The input current during testing was 0.760 A and the time scale was the same 50 microseconds. The results showed that there was no noticeable phase tripping (see FIGURE 18). (15.)

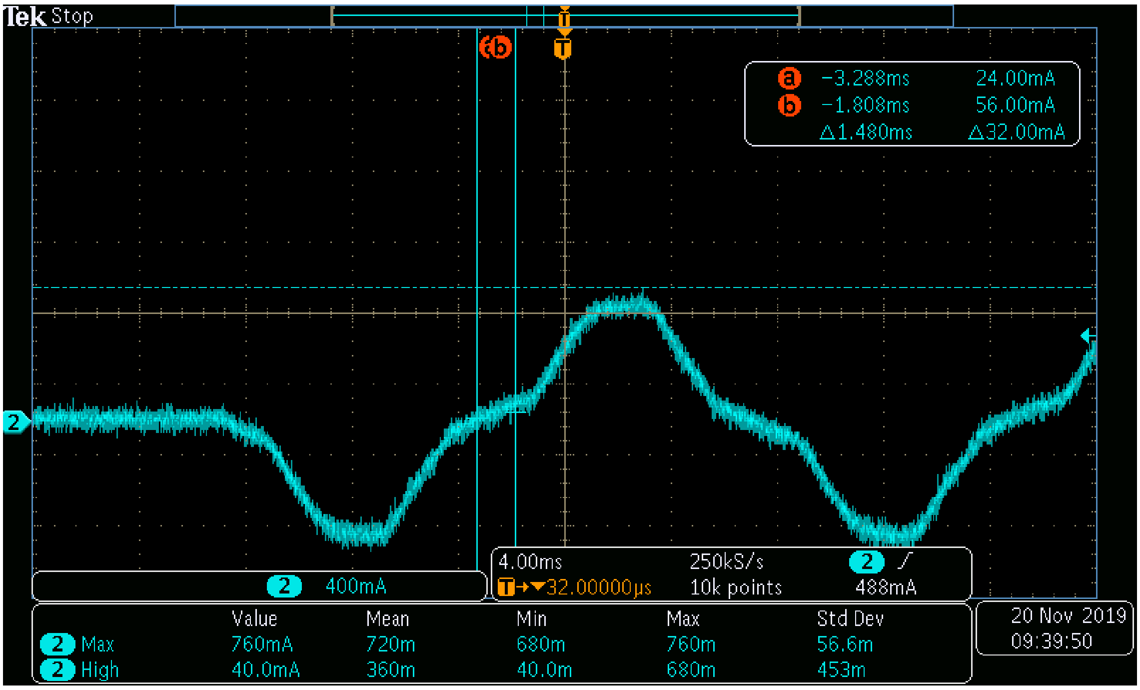


FIGURE 18: Inrush current phase angle 360 degrees Elcart (15.)

8.2.5 Conclusion of the test results

The test was successful and was done under the test parameters. The testing showed that the tripping time and current for the LED strips are considerably smaller compared to the fluorescent lights. The end test results for both Weco and Elcart were very similar and did pass tests regarding the new LED shaft light concept. Both Weco and Elcart LED strips had very short balancing time for the spike and both of them seemed to have also very low inrush current. The test was to be made also for the Crosspoint manufacturer's LED strip but due to the light efficiency test, which it did not pass, the Crosspoint was not tested.

8.3 Insulation resistance test

This paragraph contains the insulation current test plan and test results. For both Weco and Elcart one 50 meter test sample were tested. The acceptance criteria for the testing were that the insulation resistance must be ≥ 0.5 MΩ during the testing for ensuring the quality of insulation. The maximum testing voltage was to be 500 VDC and the LED strip sample must still be able to work after testing. (15.)

The testing was needed to be done in three different steps:

- Step 1: Check that the both main switches are switched in OFF position.
    - Main switch Q220 (see FIGURE 19)
    - Main switch, light Q262 (see FIGURE 19)
- Step 2: Measure insulation resistance between PE and lighting switch (L, N) load side using 500 VDC test voltage.
- Step 3: Turn ON the light to check that it is working after testing. (15.)

8.3.1 Test equipment specifications

Electrical testing was performed with a complete test elevator using specific instrument to measure insulation resistance (Megger). (15.)

8.3.2 Test results: Insulation resistance

The insulation resistance measuring was done according to the test plan by the steps defined earlier. This testing is crucial to ensure that the elevators insulation is in adequate condition and it provides a ground for other readings to use as a reference for future testing.

The first measurement was done by connecting the measuring instrument Meager to the elevator main PE terminal inside the elevator control cabinet. The end results were that the PE terminal between L and N terminal connections had both over 550 MΩ resistance. (15.)

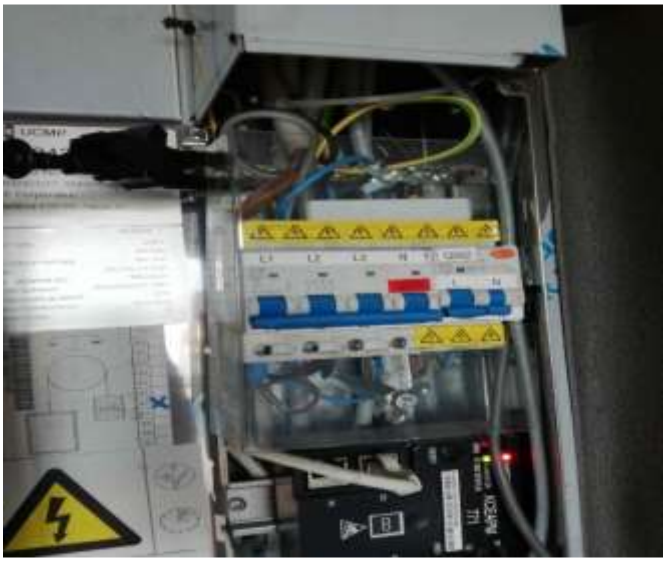


FIGURE 19: Insulation resistance measurement between ground (PE) to L and N terminals (15.)

The insulation resistance test results between PE and L terminals were over 550 MΩ. The test was done by using 527 VDC measured with voltage meter. The test were successful and passed the required 500 MΩ minimum value (see FIGURE 20). (15.)

FIGURE 20: Insulation resistance measurement test results between PE and L terminals (15.)

The insulation resistance test results between PE and L terminals were over 550 MΩ. The test was done by using 526 VDC measured with voltage meter. The test were successful and passed the required 500 MΩ minimum value (see FIGURE 21). (15.)

FIGURE 21: Insulation resistance measurement test results between PE and N terminals (15.)

8.3.3 Conclusion of the insulation test results

The test results show that the insulation resistance with every manufacturers samples were successfully above the needed criteria ≥ 0.5 MΩ and all the manufacturers pass the test after every test step (see TABLE 28.). (15.)

TABLE 28: Results table for manufacturer samples (15.)

	Manufacturers		
Testing points	Weco	Elcart	Crosspoint
L To PE	**PASSED**	**PASSED**	**PASSED**
N To PE	**PASSED**	**PASSED**	**PASSED**

8.4 Tearing test

This section contains the tearing test plan and test results. Due to the long travelling heights LED strips can have when installed to the shaft for a long period of time the tearing test is needed to ensure that the LED strip will continue to work under harsh conditions and will still have a long life expectation. The test sample LED strip is targeted with a lot of pulling force to see and verify how it handles wearing directly compared to time in use.

The hydraulic cylinder would pull the DUT connected between two wedges while the force is measured using digital weight calculator. The test bench would steadily increase the pulling force to the DUT until it fails the test. The breaking point was detected using the photo resistor planned near the DUT (see FIGURE 22). The results were marked in a table. The test was applied to five (5) different samples of each manufacturer. The test steps were: (15.)

- Step 1: Hang up the DUT fixing the lower side to a fixed point pulling the upper side
- Step 2: Samples will be in 1 meter length with junction connection middle of the DUT
- Step 3: Turn the DUT ON
- Step 4: Pull the DUT
- Step 5: Record the force applied to the DUT when the lights goes OFF (malfunction)
- Step 6: Repeat the test for each manufacturers 5 different samples. (15.)

8.4.1 Test equipment specifications

A specific rig was used for the tearing test. This rig contained two yellow cable glands, a weight measuring sensor and a high speed camera to record the test results in case of malfunctioning of the strip (see FIGURE 22). (15.)

FIGURE 22: Tearing test bench setup (15.)

8.4.2 Tearing test results: Weco

Weco LED strip performed well with the pulling test. The pulling force was measured to be approximately 240 N with Weco sample. Tests were repeated five times to make sure the given results remain the same (see TABLE 29). (15.)

TABLE 29: Weco LED FLEX 05.BN6 rope light tearing test results. (15.)

Weco LED FLEX 05.BN6 Rope light	
Test n°	F_{MAX} [N]
1	**239**
2	**220**
3	**239**
4	**246**
5	**248**

After the testing pictures of the failed strips were taken for studying how the straight pulling force affected the lighting strip. The FIGURE 23 clearly shows the effects of the pulling tests. The PFC board has been stretched and snapped to two different pieces braking the electrical connection inside the strip from the junction point. Outside silicone sleeve remained intact. (15.)

FIGURE 23: Failed LED strip Weco (15.)

8.4.3 Tearing test results: Crosspoint

Crosspoint manufacturer's LED strip was a little more resistive than Weco but the difference for real life assembly would not give it a specific advantage when comparing it to other manufacturers products. The test was repeated five times to make sure the given results remain the same (see TABLE 30). (15.)

TABLE 30: Crosspoint rope light tearing test results. (15.)

Crosspoint rope light	
Test number	F_{MAX} [N]
1	**329**
2	**292**
3	**294**
4	**313**
5	**301**

After the testing pictures of the failed strips were taken for studying how the straight pulling force affected to the lighting strip. The FIGURE 24 clearly shows the effects of the pulling tests. The PFC board has been stretched and snapped to two different pieces braking the electrical connection inside the Crosspoint strip from the junction point. Outside silicone sleeve remained intact. (15.)

FIGURE 24: Failed LED strip Crosspoint (15.)

8.4.4 Tearing test results: Elcart

Elcart manufacturer's LED strip behaved the same way as the other manufacturers samples. It showed some variations in values but these remain still in presumed range. Test was repeated five times to make sure the given results remain the same (see TABLE 31). (15.)

TABLE 31: Elcart LED FLEX 96/9986 tearing test results. (15.)*

Elcart LED FLEX 96/9986*	
Test number	F_{MAX} [N]
1	**256**
2	**285**
3	**301**
4	**273**
5	**294**

After the testing pictures of the failed strips were taken for studying how the straight pulling force affected to the lighting strip. The FIGURE 25 clearly shows the effects of the pulling tests. The PFC board has been stretched and snapped to two different pieces braking the electrical connection inside the Elcart strip from the junction point. Outside silicone sleeve remained intact. (15.)

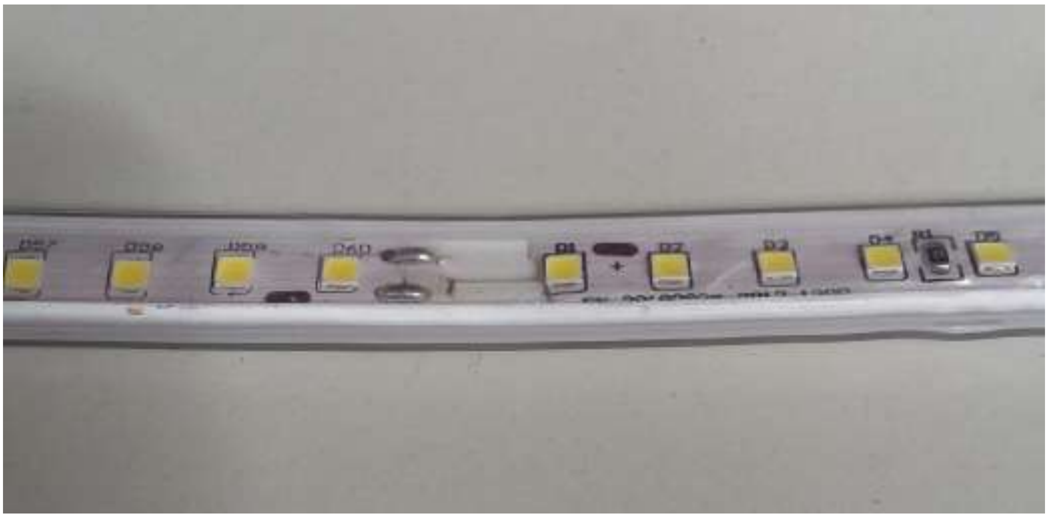


FIGURE 25: Failed LED strip (Elcart) (15.)

8.5 Bending test

Bending test was performed for the samples to establish functionality and behavior of the strip. The test is passed when the sample is still working after bending cycles by turning it ON position. The testing was performed in the following steps:

- Step 1: Connect DUT to the test bench
- Step 2: Test the strip by switching it ON / OFF
- Step 3: Bend the strip wrapped around internal reel diameter (6 cm) from the narrow side 10 times and in 3 series. After bending try to switch strip back ON then OFF. If everything works proceed to step 4
- Step 4: Bend the strip now by making U–shape with it (1 cm). Apply this 10 times and 3 series. After every bending series try to switch strip back ON then OFF
- Report the result as PASS or FAILED to the results table
- Repeat test for 5 samples for each supplier (1 meter in length). (15.)

8.5.1 Specification for the test equipment

To perform bending test two different types of bending radius were applied to the samples. The first test was done by using six centimeter thick reel seen in FIGURE 26. The LED strip is wrapped against the reel and then the strip would be pulled until it will pass the reel. After bending the LED strip will be turn back ON to check functionality. (15.)

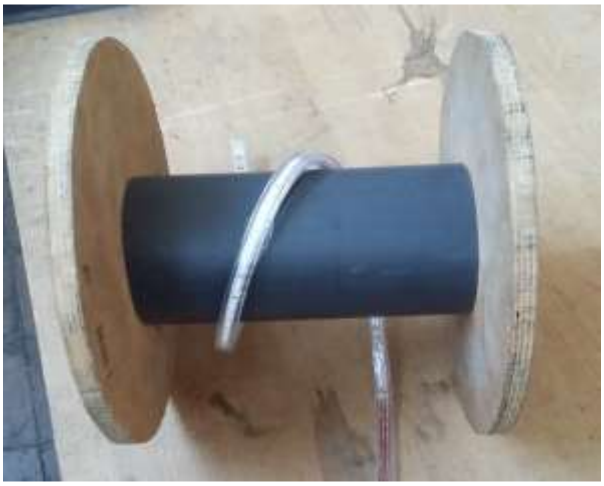


FIGURE 26: Bending tool with 6cm radius (15.)

For the next bending test the fingers were used to bend the strip in the way shown in the FIGURE 27. As a result, the strips bent radius would be around 1 cm. After bending the LED strip would be turned back ON position to check the functionality. (15.)

FIGURE 27: Bending with fingers 1cm radius (15.)

8.5.2 Bending test results

The tests were done for every manufacturers samples using the same test equipment and environment. It was crucial to use enough force when bending so that the needed results would simulate the real life scenario. The first test sample to be tested was from manufacturer Weco. Both the 6 cm radius and 1 cm radius bending tests were carried out and gave the passing results (see TABLE 32). (15.)

TABLE 32: Weco LED FLEX 05.BN6 bending test results (15.)

Weco LED FLEX 05.BN6			
Test type	10 times / 1st series	10 times / 2nd series	10 times / 3rd series
Narrow side (r=6 cm)	**PASSED**	**PASSED**	**PASSED**
U-shape (r=1 cm)	**PASSED**	**PASSED**	**PASSED**

The next tested LED was from manufacturer Elcart. Both the 6 cm radius and 1 cm radius bending tests were carried out and gave the passing results (see TABLE 33). (15.)

TABLE 33: Elcart LED FLEX 96/9986 bending test results (15.)*

Elcart LED FLEX 96/9986*			
Test type	10 times / 1st series	10 times / 2nd series	10 times / 3rd series
Narrow side (r= 6 cm)	**PASSED**	**PASSED**	**PASSED**
U-shape (r=1 cm)	**PASSED**	**PASSED**	**PASSED**

The last tested LED was from manufacturer Crosspoint. Both the 6 cm radius and 1 cm radius bending tests were carried out and gave the passing results (see TABLE 34). (15.)

TABLE 34: Crosspoint rope light bending test results (15.)

Crosspoint rope light			
Test type	10 times / 1st series	10 times / 2nd series	10 times / 3rd series
Narrow side (r= 6 cm)	**PASSED**	**PASSED**	**PASSED**
U-shape (r= 1 cm)	**PASSED**	**PASSED**	**PASSED**

As seen from the test results every manufacturers samples passed the bending test. For Weco sample the only concern was related to the weakest part of the LED strip which was the connection part between the LED strip and the transformer. The seal survived the testing and remained its functionality and its IP rating.

9 COST VALUATION

For the new elevator LED light concept it was essential to find out the cost valuation compared between the new LEDs and old fluorescent type of lights. Because the LEDs are known to have easier installation method and longer lifespan the presume results were that the new LED strip will be more cost efficient, maintenance free and easier to install to the shaft or machinery area. It also provides better illuminating performance per square meter and thus is clearly a more suitable option regarding the future needs and updateability regarding the new standard EN 81-20.

The standard demands minimum of 20 lux in any measured area in elevator shaft which would increase the cost of a current system due to the fact that halogen light modules would need to be placed every 7 meters to ensure at least 20 lux in the shaft and 200 lux in the machinery area. (4.) (5.)

9.1 Halogen light cost valuation

The current halogen shaft light in use costs around 17.30 € per piece. This is more compared to the new solution which does not need these types of separate lighting modules. One disadvantage for the halogen lamp is that its luminating area is smaller compared the LED strip. In case of the new standard halogen lamp modules would have to be installed continually per 7 meters to be able to maintain the needed lux values and to meet the new requirements of the standard EN 81-20 (see TABLE 35). (APPENDIX 1.)

TABLE 35: Cost for halogen light in use (APPENDIX 1.)

HALOGEN LIGHT			
CURRENT L&S SHAFT LIGHT	**Price for Piece**	**Test elevator 12,00 m**	**Test elevator 18,00 m**
SHAFT LIGHT, LED LAMP CABLE	17,30 €	51,90 €	69,20 €
CABLE, SHAFT LIGHT L = 6,00 m	6,20 €	18,60 €	24,80 €
HALOGEN LIGHT ASSEMBLY	13,90 €	13,90 €	13,90 €
CABLE, CTL - SHL L = 7,00 m EN	11,59 €	11,59 €	11,59 €
FIXING KIT (cable ties + plugs)	1,22 €	3,66 €	4,88 €
TOTAL		99,65 €	124,37 €

9.2 LED strip cost valuation: Weco

The first commercial LED strip is from manufacturer Weco. It provides LED strip in cost of 1.99 € / m. The most expensive part of the LED strip costs are strips cut to length cost (6,00 €) and LED driver with the connecting power supply cable (5,45 €). These are the most expensive parts of the solution implementation (see TABLE 36). (APPENDIX 2.)

TABLE 36: Cost valuation for Weco LED strip (APPENDIX 2.)

Weco LED strip cost table			
CURRENT L&S SHAFT LIGHT	**Price for Piece**	**Test Elevator 12,00 m**	**Test Elevator 28,00 m**
SHAFT LIGHT, LED STRIP €/m	1,99 €	37,81 €	55,72 €
CUT TO LENGTH	6,00 €	6,00 €	6,00 €
LED Driver & Power supply cable (5m)	5,45 €	5,45 €	5,45 €
Cable for socket and switch (4G1,5)	0,90 €	10,80 €	16,20 €
Cable from MAP to LED strip (7m) 2x1,5	0,60 €	4,20 €	4,20 €
Needed improvement on top and bottom ends for reliable connection	3,00 €	3,00 €	3,00 €
FIXING KIT (cable ties + plugs)	1,22 €	3,66 €	4,88 €
TOTAL		70,92 €	95,45 €
TOTAL SAVINGS		-28,73 €	-28,92 €

9.3 LED strip cost valuation: Elcart

The next commercial LED strip is from manufacturer Elcart. It provides LED strip in cost of 2,50 € per one meter. The most expensive part of the LED strip costs are strips cut to length cost (6,00 €) and LED driver with power supply cable (4,80 €). These are the most expensive parts of the solution implementation (see TABLE 37). (APPENDIX 3.)

TABLE 37: Cost valuation for LED strip Elcart (APPENDIX 3.)

Elcart LED Strip cost table			
CURRENT L&S SHAFT LIGHT	**Price for Piece**	**MonoS-pace500 / EcoSpace 12,00 m**	**MonoS-pace500 / EcoSpace 28,00 m**
SHAFT LIGHT, LED STRIP €/m	2,50 €	47,50 €	70,00 €
CUT TO LENGTH	6,00 €	6,00 €	6,00 €
LED Driver & Power supply cable (5m)	4,80 €	4,80 €	4,80 €
Cable for socket and switch in the pit (4G1,5)	0,90 €	10,80 €	16,20 €
Cable from MAP to LED strip (7m) 2x1,5	0,60 €	4,20 €	4,20 €
Needed improvement on top and bottom ends for reliable connection	3,00 €	3,00 €	3,00 €
FIXING KIT (cable ties + plugs)	1,22 €	3,66 €	4,88 €
TOTAL		79,96 €	109,08 €
TOTAL SAVINGS		-19,69 €	-15,29 €

9.4 Conclusion of the cost valuations

Comparison between the halogen light power module (17,30 €) and LED strip and driver (7,44 €) highlights the benefits of the LED based on solution. For example in 7 meters the cost would be with one halogen module around 51,90 € and using the LED strip it would be around 37,81 €. In long shaft distances the LED strip will be considerably cheaper and a cost efficient solution. The LED lights were also easier to install and maintain what lowers the costs even more. The purchase price comparison for the Crosspoint manufacturer’s LED light was not needed due to the earlier failed test results.

10 SUMMARY

This thesis was produced in accordance with the scope of KONE's demands and expectations regarding the new LED concept for the upcoming EN 81-20 standard lighting norm. The concept verified that the LEDs are the most reliable way known today to implement lighting solution for harsh conditions with a small area if the acceptance criteria are considered to be the most cost-efficient, maintenance-free, energy-efficient, and solution friendly way to produce light.

The thesis contained some basic principles and functions of the LEDs, laboratory test cases, defining the acceptance criteria and designing the new solution. Test results demonstrated the benefits of LED lights and as continuing testing the overall observation was that the LEDs are the best solution regarding the the demands of the new standard.

With the new LED concept the company can move to the next stage to start implementing the solution towards as a working product for the next generation elevators. The requirement specification will also set up new guidelines for choosing acceptable products. The thesis focused mainly on the elevator type of solutions in the harshest conditions such as the machinery and shaft area leaving the other types of needs for lighting untouched such as inside the elevator car. This thesis could be very easily continued regarding the topic and could benefit some new type of modern lighting control solutions.

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PURCHASING PRICES FOR HALOGEN LIGHT APPENDIX 1

PURCHASING PRICES FOR CURRENT LED LIGHT SOLUTION

BUSINESS CASE – Current LED light solution

KONE

			CURRENT SHAFT LIGHTING SOLUTION (LED LIGHTS)	
CURRENT L&S SHAFT LIGHT implemented from September 2018	**Material Code**	**Price per PC**	**MonoSpace500 / EcoSpace 12m travel (630kg)**	**MonoSpace500 / EcoSpace 18m travel (1000kg)**
SHAFT LIGHT, LED LAMP WO CABLE	KM51457454G03	€ 17,30	€ 51,90	€ 69,20
CABLE,SHAFT LIGHT L=6M	KM750266G01	€ 6,20	€ 18,60	€ 24,80
HALOGEN LIGHT ASSEMBLY	KM51082300G10	€ 13,90	€ 13,90	€ 13,90
CABLE, CTL-SHL L=7M EN (5G1,5)	KM796226G12070	€ 11,59	€ 11,59	€ 11,59
FIXING KIT (cable ties + plugs)	KM713862G02	€ 1,22	€ 3,66	€ 4,88
TOTAL			€ 99,65	€ 124,37

WECO PURCHASING PRICES FROM MANUFACTURER

BUSINESS CASE – LED STRIPE (material costs)
Scenario 1a (WECO LED stripe only)

LED STRIPE ONLY

		NEW SHAFT LIGHTING SOLUTION (LED STRIPE)		
WECO LED Stripe		Price per m	MonoSpace500/EcoSpace 12m (630kg) 19mt LED stripe (Headroom + Shaft + Pit)	MonoSpace500/EcoSpace 18m (1000kg) 28mt LED stripe (Headroom + Shaft + Pit)
LED STRIPE		€ 1,99	€ 37,81	€ 55,72
Cut to length		€ 6,00	€ 6,00	€ 6,00
LED Driver & Power supply cable (5mt)		€ 5,45	€ 5,45	€ 5,45
Cable for socket and switch in the pit (4G1,5)		€ 0,90	€ 10,80	€ 16,20
Cable from MAP to LED stripe (7mt) 2x1,5		€ 0,60	€ 4,20	€ 4,20
Unidentified improvement on top and bottom ends for reliable connection		€ 3,00	€ 3,00	€ 3,00
FIXING KIT (cable ties + plugs)	KM713862G02	€ 1,22	€ 3,66	€ 4,88
TOTAL			€ 70,92	€ 95,45
TOTAL SAVING			-€ 28,73	-€ 28,92

Notes:
- Weco solution has quality issues to be solved
- if not LOW PIT/HEADROOM elevator: Travel high = 12m --> Shaft high = 12m + 4m = 16m; Travel high = 18m --> Shaft high = 18m + 4m = 22m
  16m + 3m = 19m LED stripe (considering L shape at Headroom); 22m + 6m = 28m LED stripe (considering L shape at Headroom)
- Connection between LED stripe and MAP inside Machinery trunking
- Business case assuming that no additional lights are needed to reach 200Lux at Machinery area (to be tested)
- Unidentified improvement on top and bottom ends of LED stripe to have reliable connection between driver and LED stripe (at the top) and to insulate LED stripe after cutting (at the bottom)

ELCART PURCHASING FROM MANUFACTURER

BUSINESS CASE – LED STRIPE (material costs)
Scenario 1b (ELCART LED stripe only)

LED STRIPE ONLY

			NEW SHAFT LIGHTING SOLUTION (LED STRIPE)	
ELCART LED Stripe		Price per m	MonoSpace500/EcoSpace 12m (630kg) 19mt LED stripe (Headroom + Shaft + Pit)	MonoSpace500/EcoSpace 18m (1000kg) 28mt LED stripe (Headroom + Shaft + Pit)
LED STRIPE		€ 2,50	€ 47,50	€ 70,00
Cut to length		€ 6,00	€ 6,00	€ 6,00
LED Driver & Power supply cable (6mt)		€ 4,80	€ 4,80	€ 4,80
Cable for socket and switch in the pit (4G1,5)		€ 0,90	€ 10,80	€ 16,20
Cable from MAP to LED stripe (7mt) 2x1,5		€ 0,60	€ 4,20	€ 4,20
Unidentified improvement on top and bottom ends for reliable connection		€ 3,00	€ 3,00	€ 3,00
FIXING KIT (cable ties + plugs)	KM713862G02	€ 1,22	€ 3,66	€ 4,88
TOTAL			€ 79,96	€ 109,08
TOTAL SAVING			-€ 19,69	-€ 15,29

Notes:
- ELCART solution seems has not quality issues (light efficiency tested in Pero - Black box)
- if not LOW PIT/HEADROOM elevator: Travel high = 12m --> Shaft high = 12m + 4m = 16m; Travel high = 18m --> Shaft high = 18m + 4m = 22m
  16m + 3m = 19m LED stripe (considering L shape at Headroom); 22m + 6m = 28m LED stripe (considering L shape at Headroom)
- Connection between LED stripe and MAP inside Machinery trunking
- Business case assuming that no additional lights are needed to reach 200Lux at Machinery area (to be tested)
- Unidentified improvement on top and bottom ends of LED stripe to have reliable connection between driver and LED stripe (at the top) and to insulate LED stripe after cutting (at the bottom)