

A STUDY ON THE SAFETY AND PARAMETERS OF POWER DIRECT LED LAMP

Jin-Tai Kim¹ and Chung-hyeok Kim²

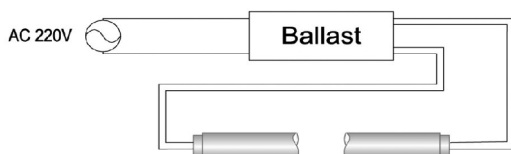
¹Korea Testing and Research Institute

²Ingenium College of Engineering, Kwangwoon University

E-mail: bighhs@naver.com

ABSTRACT

As energy problems emerge, high-efficiency lighting devices that can replace conventional lighting are required to save energy, and among them, LED (light emitting diode) lighting has begun to emerge as the next-generation lighting. Since LED has low power, high efficiency, long lifetime, and fast response speed, it is suitable to replace existing lighting such as incandescent lamps, fluorescent lamps, and halogen lamps. The present study proposes safety of household appliances to prevent a degraded replacement effect due to excessive luminous flux of an LED lamp that replaces a bending-type fluorescent lamp (FPL), to prevent excessive design investment for manufacturers by providing appropriate optical reference values, to identify safety issues during the installation of AC power direct LED lamps, and to standardize the optimal power supply method that can be fixed by using the LED lamp based on external converters and the LED lamp for fluorescent lamp replacement.



Ballast: A device for operating fluorescent lamps (AC input-AC output)

Fig. 1. Fluorescent lamp replacement type LED lamp – built-in converter type (the certified lamps and ballasts for fluorescent lamps can be used without modification)

Keywords: LED luminaire, LED lighting, safety standards for electrical appliances, electrical appliances safety standards in Korea, electrical safety management, safety certification, ballast, power direct, power supply, connection method

1. INTRODUCTION


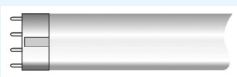
1.1. Background of the Present Study

The LED lighting market has rapidly appeared due to the rapid growth of the green energy business since 2009. Furthermore, to meet the demand for energy saving, LED light sources are being replaced by traditional light sources with low energy efficiency. The light source has evolved from candles in the past, to incandescent lamps, fluorescent lamps, and LED lamps.

LED light sources have been replacing fluorescent lamps, and related luminaire are appearing in the market. In particular, the fluorescent replacement LED lamps have been actively developed to increase energy efficiency and reduce the use of mercury for environmentally friendly factors. Fluorescent lamps have been used most often in homes, offices, and industrial facilities, and recently, G13 cap's linear-type LED lamps are actively being used.

Furthermore, safety standards have been recently enacted (14.4.30) for LED lamps and linear-type LED lamps, which can replace the conventional FPL fluorescent lamps (FPL) used in homes in Korea, and certified to be distributed and commercialized.

Table 1. FPL LED Lamp Safety Standard (KC10025)

Item	Linear type (G13 cap)		FPL type (2G11 cap)	
Shape				
Power, W	20, 32, 40		36, 55	
Luminous flux standard	20 W	1100 lm → 858 lm	36 W	2590 lm → 2202 lm
	32 W	2300 lm (simulation)	55 W	4000 lm → 3400 lm
Note	The calculated luminous flux is 85 % of the luminous flux standard of KS C7601 (fluorescent lamp)			

There are different types of LED lamps. The first type is shown in Fig. 1 and it is the so-called G13/2G11 cap-shaped fluorescent lamp replacement LED lamp—built in converter, which only uses LED lamps. The second type is G13 linear type with an external converter, as shown in Fig. 2. The final type of LED lamp is shown in Fig. 3, where 220 V commercial power is supplied to the LED lamp caps of the linear type with a G13 cap and the FPL type with a 2G11 cap. [1]

Criteria for the optical characteristics of the linear type LED lamp can be found in the safety standards (KC) for the conventional fluorescent lamp replacement type LED lamp—built-in converter and the linear type LED lamp—external converter. Furthermore, the criteria for the linear type FPL LED lamps are only discussed in the safety standards of the conventional fluorescent lamp replacement type LED lamp—built-in converter (KC10025). However, as shown in Table 1, because the suggested value is defined as 85 % or higher of the standard value of the fluorescent lamp (KS C7601), rather than the actual measurement data, research needs to be conducted to determine whether fluorescent lamps can be replaced by those LED lamps or not. [2]

The fluorescent lamp replacement LED lamp can save time and money by using existing luminaires for fluorescent lamps without modification. Therefore, compared to the case where new LED luminaires need to be installed, the burden for the

installation can be relatively reduced and the existing luminaires for fluorescent lamps can be recycled without discarding them. Therefore, these luminaires have three main advantages: high efficiency, long lifetime, and eco-friendliness.

The linear type lamps are classified as:

1. The fluorescent lamp (1200 mm 32 W, 36 W, 40 W);
2. The LED lamp-external converter;
3. The fluorescent lamps replacement type (ballast compatible);
4. The power direct-type LED lamp.

Among them, the first, second, and third can be certified through the KC certification by the National Institute of technology and standards, but the fourth (the power direct-type LED lamp) has not been certified due to the lack of safety items to be tested, such as standardization of the power system when a LED lamp is used with conventional lamps and fluorescent light bulbs having the same shape as the LED lamp. As a result, due to the lack of certification standards, the demand for certification by Korean companies is increasing rapidly.

When direct-type LED lamps are supplied, it is expected that problems such as fire, electric shock, and burning accidents may arise due to misuse of lamps with different power supply methods. Therefore, this paper will study and analyse the problems

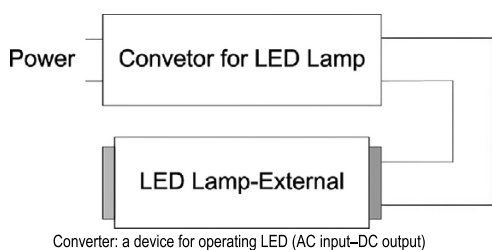


Fig. 2. Linear LED lamp – external converter type (an LED converter and an LED lamp with AC/DC50 V or lower)

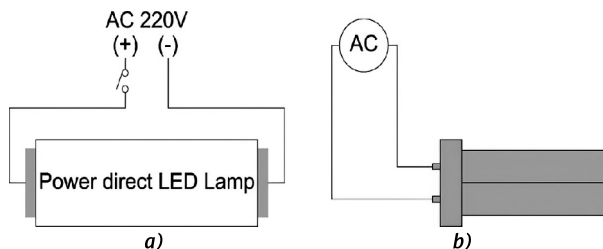


Fig 3. Power direct LED lamp (a) and FPL lamp (b) (this is a 220 V direct input method, where a converter and an LED lamp are integrated)

Table 2. Linear LED Lamp Certification Status

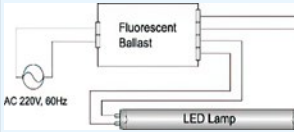
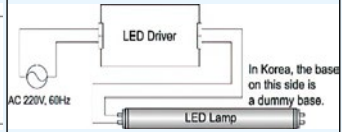
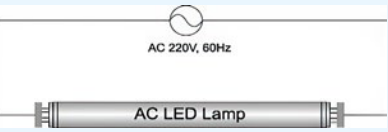
Method	Compatible ballast	External converter	220 V power direct
Circuit			
Manufacturer	20 companies	300 companies	No certified companies exist *foreign manufacturing companies cannot sell in Korea
Standard trend	Established in 2/25/2013	Established in 12/21/2010	–
Standard number	KC10025 (G13 base)	KC20001 (G13 and D12 bases)	–
International standard	IEC62776 (G13 and G5 bases)	IEC62931 (GX16t-5 base)	–

Table 3. Linear LED Lamp – External Converter Type

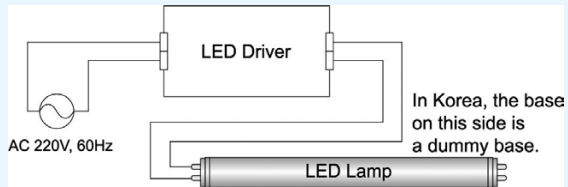
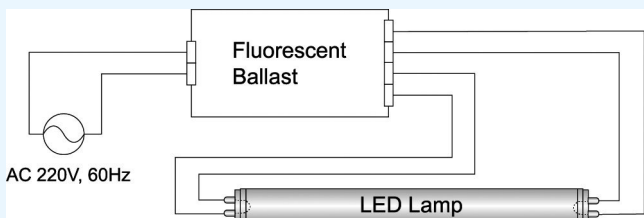
Lamp type (date of notice on safety standards)	LED converter and LED lamp below AC/DC50V used ⇒ (Notice of Electrical Appliances Safety Standards: 2010.12.21)
Structure	

Table 4. Fluorescent Lamp Replacement Type LED Lamp – Built-in Converter Type

Lamp type (date of notice on safety standards)	Certified luminaires and ballasts for fluorescent lamps are used without modification ⇒ (Notice of Electrical Appliances Safety Standards: 2013.03.25)
Structure	

of the conventional fluorescent lamps and the expected problems in the actual use of those lamps, which are summarized in Tables 2, 3 and 4.

Furthermore, safety standards for electrical appliances (KC) will be established to ensure that safe and high-quality products are distributed, and consumers can use safe products.

Therefore, with this study, it is possible to derive the safety problems that can occur when the direct-type LED lamp, which is shown in Table 4, is attached to the conventional fluorescent lamp and the luminaires shown in Table 2 and Table 3, and

to ensure safety when using them together by standardizing the optimum power supply method. Furthermore, the conventional FPL fluorescent lamps are mounted on a luminaire, and the lamp power, luminous flux, and illuminance are measured and analysed to study optimized optical characteristics that can replace the conventional lamps, based on which the domestic electrical appliance safety standards (KC) will be proposed.

Table 5 shows the connection circuit for the power direct LED lamp, which will be analysed in this work.

Table 5. Power Direct LED Lamp

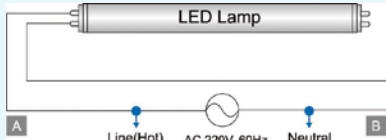
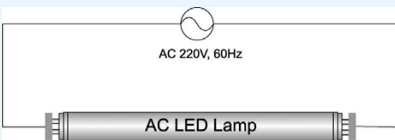
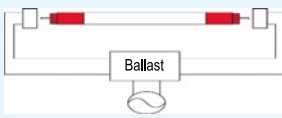
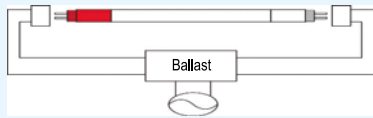
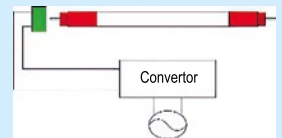
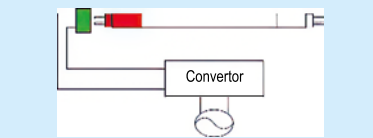
<p>Lamp type (date of notice on safety standards)</p>	<p>220 V direct input method is used and a converter and an LED lamp are integrated ⇒ Absence of safety standards</p>	
<p>Structure</p>	 <p>Input in one side</p>	 <p>Input in both sides</p>

Table 6. Direct Power LED Lamp Cross Table

Item	Power direct LED lamp	
	Connection method 1	Connection method 2
Luminaires for fluorescent lamp / LED lamp for replacing a fluorescent lamp with a built-in converter		
LED Lamp-external converter type		

2. MATERIALS AND METHODS

This study analyses the risks when the power direct-type LED lamps are installed in the conventional luminaires for fluorescent lamps and LED lamp built-in converter type and LED lamp-external converter, which are shown in Table 6, for safety investigation. Furthermore, as shown in Table 7, the risks are analysed when the LED lamp-external converter is installed in the existing luminaires for fluorescent lamps and luminaires for power direct-type LED lamps, and as shown in Table 8, the risks are analysed when the fluorescent lamps and fluorescent lamp replacement LED lamps are installed in luminaires for the LED lamp-external converter and luminaires for the power direct-type LED lamps.

Based on the analyses, problems such as compatibility, electric shock, and fire risk were derived:

1. The products that were certified by KC10025 (fluorescent lamp replacement type LED lamp-built-in converter) were analysed and the suitability for the specified luminous flux was confirmed as shown in Table 1;

2. The revised proposal was made by comparing and analysing the luminaire parameters for three FPL 36 W lamps with fluorescent lamps and LED lamps respectively;

3. The revised proposal was made by comparing and analysing the luminaire parameters for three FPL 55 W lamps with fluorescent lamps and LED lamps respectively to propose safety standards.

In addition, the reason why a luminaire with three FPL lamps was used for testing is that this type of luminaire is most common in household applications.

The optical properties were measured in accordance with Annex B of IEC60901: Single-capped fluorescent lamps—Performance specifications and illuminance simulations were analysed with a Goniophotometer (LMT, Germany) in accordance with Annex A of KS C8000: General rules for lighting equipment. The lighting method of the luminaire was measured by connecting the test ballast specified in KS C7601 (fluorescent lamp) standard as shown in

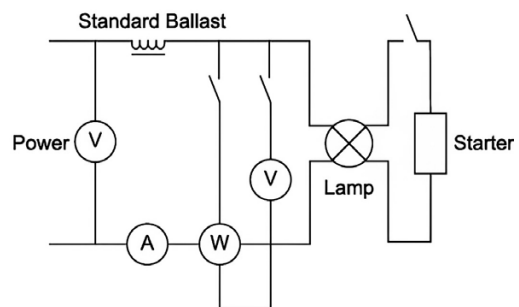


Fig. 4. Test circuit

Table 7. Converter External LED Lamp Cross Table

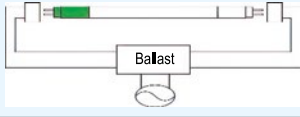
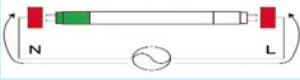
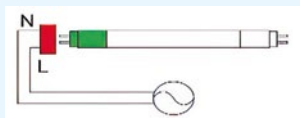
Item	LED lamp-external converter type	Note
Luminaire for fluorescent lamp		-
Luminaire for power direct LED lamp		Connection method 1
		Connection method 2

Table 8. Fluorescent Lamp and LED Lamp Built-In Converter Type Cross Table

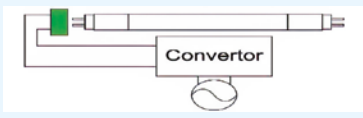
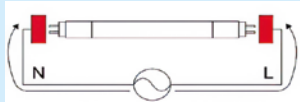
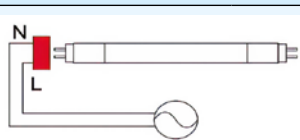
Item	Fluorescent lamp	LED lamp built-in converter	Note
Luminaire for LED lamp-external converter type			-
Luminaire for power direct LED lamp			Connection method 1
			Connection method 2

Table 9. Certified Product Analysis Results

Parameter	Unit	FPL 36 W			FPL 55 W	
		Fluorescent lamp		LED lamp	Fluorescent lamp	LED lamp
		A	B			
Luminous flux	lm	5410	5733	6558	8295	9948
Luminaire power	W	91	101	54	159	94
Luminous efficacy	lm/W	59.5	57.0	121.4	52.2	105.8
Floor surface average illuminance	lx	150	161	215	218	319

Table 10. Comparison Characteristics of FPL 36 W Fluorescent Lamp with LED Lamp

Parameter	Unit	Luminaire for three FPL 36 W lamps	
		Fluorescent Lamp	LED Lamp
Luminous flux	lm	5733	4967 (1902)
Luminaire power	W	101	42 (14)
Luminous efficacy	lm/W	57.0	117.9
Floor surface average illuminance	lx	161	160

Table 11. Comparison Luminaire Characteristics with FPL 36 W Fluorescent Lamp and LED Lamp

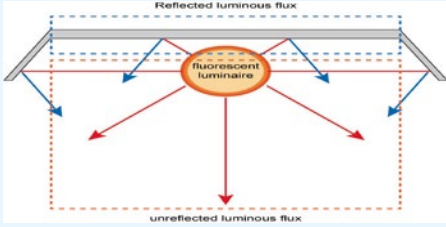
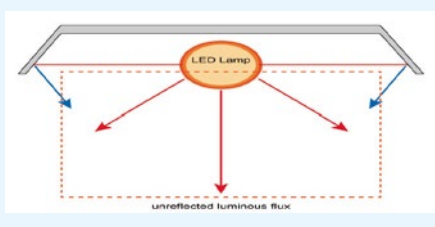
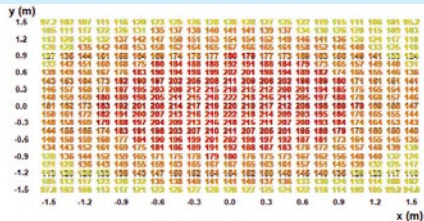
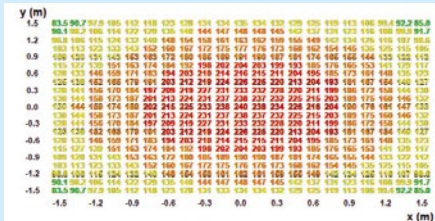
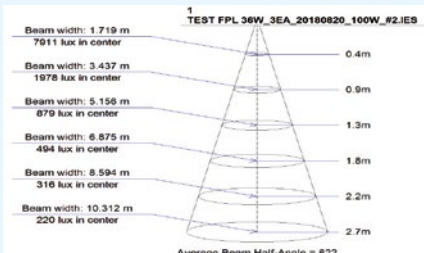
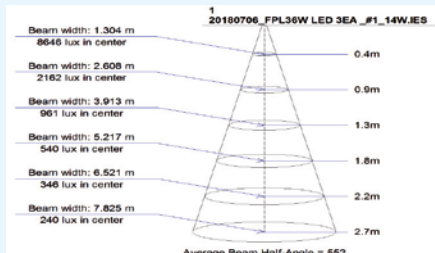
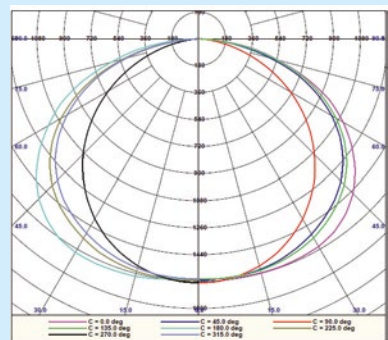
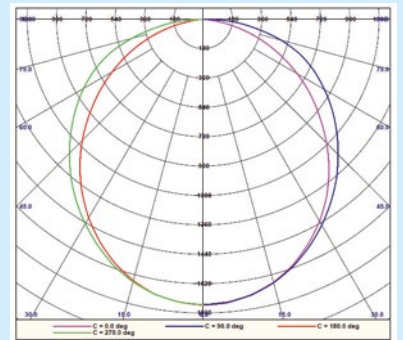
Type Item	Luminaire for fluorescent lamp (FPL 36 W×luminaire for three lamps)	LED luminaire (FPL 14 W×luminaire for three lamps)
Luminaire Operation conceptual diagram		
Illuminance distribution	 <p>Horizontal Illuminance All illuminance values in lux Table Average: 161 Table Maximum: 222 Table Minimum: 94.8 Mounting Height = 2.7 m</p>	 <p>Horizontal Illuminance All illuminance values in lux Table Average: 160 Table Maximum: 240 Table Minimum: 83.5 Mounting Height = 2.7 m</p>
Illuminance	 <p>Average Beam Half-Angle = 62°</p>	 <p>Average Beam Half-Angle = 55°</p>
Distribution curve (of luminous intensity)		

Fig. 4, and measurements were made in a darkroom at 25 °C ± 1 °C. [3]

3. TEST RESULTS

For cross-sectional analysis, safety studies were conducted for two connection methods (the first method and the second method), as shown in Table 8, and the measurement results according to IEC60901 and KS C8000 are as follows.

Product analysis showed that replacing the fluorescent lamp FPL 36 W with a KC10025 certified commercially produced LED lamp with a built-in

current converter provides a higher illuminance value of 65 lx while reducing power consumption by 47 W, as shown in Table 9. In addition, if the fluorescent lamp FPL 55 W was replaced with an LED one, the illuminance level increased by 101 lx, and the power consumption decreased by 65 W. Based on this, it can be concluded that the luminous flux of LED lamps exceeds the regulated values specified in the standard, so they need to be modified. [2]

The result of a comparative analysis of an EX-D fluorescent lamp (daylight) and an LED lamp in a three-dome luminaire designed for FPL 36 W lamps is as follows: each light source was turned on at the

Table 12. Comparison Characteristics of FPL 55 W Fluorescent Lamp with LED Lamp

Parameter	Unit	Luminaire for three FPL 55 W lamps	
		Fluorescent lamp	LED lamp
Luminous flux	lm	8295	6898 (3217)
Luminaire power	W	159	70 (23)
Luminous efficacy	lm/W	52.2	98.8
Floor surface average illuminance	lx	218	219

Table 13. Comparison Luminaire Characteristics with FPL 55 W Fluorescent Lamp and LED Lamp

Type Item	Luminaire for fluorescent lamp (FPL 55 W×luminaire for three lamps)	LED luminaire (FPL 23 W×luminaire for three lamps)
Luminaire Operation conceptual diagram		
Illuminance distribution		
Illuminance		
Distribution curve (of luminous intensity)		

Table 14. Connection Diagram Suggestion

Connection	Connection diagram
Connection method 1	<p>Example power (1-3), dummy (2-4) or power (1-4), dummy (2-3)</p>
Connection method 2	<p>Example power (1-2), dummy (3-4)</p>

Table 15. Safety Inspection of Luminaires for Fluorescent Lamp and Direct Power LED Lamp

Safety product combination	Luminaire for fluorescent lamp	
	Power direct LED lamp	
	Luminaire for fluorescent lamp + Power direct LED lamp	
	Test setup	

same area in a certain space, the illuminance from the fluorescent lamp and the average illuminance from the LED lamp were evaluated under the same conditions, and the luminous flux was calculated and analysed, as shown in Tables 10 and 11.

As a result of the analysis, the luminous flux of the LED lamp was 1902 lm, and the power was 14 W at the same average illuminance. Compared to the current standard of 2202 lm shown in Table 1, it should be reduced by about 300 lm. [4]

Below are the results of a comparative analysis of EX-D fluorescent lamps (daylight) and led lamps in a three-column lamp designed for 55 W FPL lamps.

After each light source was turned on under the same conditions in the same space as in the actual




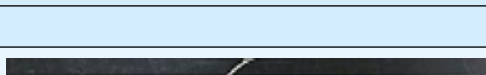


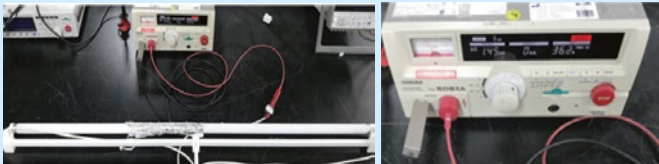
test, the point at which the illuminance from the fluorescent lamp and the led lamp are identical was evaluated, and the appropriate luminous flux was calculated and analysed. The results are shown in Tables 12 and 13.

As a result of the analysis, it was found that the luminous flux of the LED lamp was 3217 lm at the same average illuminance, and the power was 23 W. In comparison with the current standard, the value of the luminous flux should be reduced to 183 lm. [4]

A detailed connection diagram is shown in Table 14.

As a result of the cross-analysis of the luminaire for fluorescent lamp and the power direct LED

Table 16. Safety Inspection of Luminaires for Direct Power LED Lamp and Fluorescent Lamp (LED Lamp Built-In Converter)

Safety product combination	Fluorescent lamp, LED lamp built-in converter	
		
	Luminaire for power direct LED lamp	
		
	Fluorescent lamp, LED lamp built-in converter + Luminaire for power direct LED lamp	
		
Test setup		

lamp, the connection method 1 was working well and no safety problem was found. However, in the case of connection method 2, the lamp was damaged and flickered, resulting in a risk of electric shock and fire. The results of safety inspection in this case are shown in Table 15.

In the case of the connection method 1, where the luminaire for the power direct LED lamp and the fluorescent lamp were used, the lamp did not turn on and there were no safety problems occurred, and after the testing, the safety can be ensured for fluorescent lamps, as shown in Table 16. However, in the case of connection method 2, all the fluorescent lamps were damaged, resulting in the safety and electric shock problems of the lamp.

As a result of the cross test of the combination of LED lamp built-in converter and luminaire for the power direct LED lamp, the connection method 1 did not turn on the lamp and there were no safety problems occurred on the lamp and luminaire, while in case of the connection method 2, some LED lamps built-in converter were damaged, there was a safety problem occurred, and electric shock and fire risk problems were identified.

As a result of the cross test of the combination of the luminaire for power direct LED lamp and the LED lamp-external converter, the connection method 1 did not turn on the lamp, and after the testing, the lamps were normally turned on and no de-

fects or safety problems were found, as shown in Table 17.

However, in case of connection method 2, the LED lamp- external converter was damaged, smoke was generated, and a safety problem was found.

The cross-analysis of the luminaire for LED lamp-external converter and the power direct LED lamp showed that the lamps did not turn on for both connection methods. As shown in Table 18, no damages or safety problems were found, and the lamps turned on properly after the test.

4. DISCUSSION

In this study, the comparative analysis of the LED lamps, which can potentially replace the FPL 36 W and 55 W fluorescent lamps using the 2G11 cap, was conducted. Since the level of technology at the time when the existing safety certification was carried out is very different from what is currently happening, since the efficiency of the LED chip and driving part is rapidly improving due to the technology development of related companies, there is a need to revise the relevant standards in accordance with the realistic standards.

As a result of the cross-analysis according to the connection method 2 using the power direct LED lamp, the LED lamp built-in converter, the LED lamp-external converter, and the fluorescent lamp

Table 17. Safety Inspection of Luminaire for Direct Power LED Lamp and Converter External LED Lamp


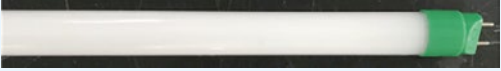

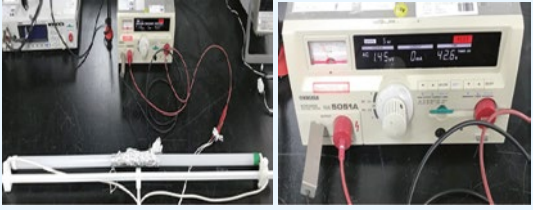




Safety product combination	Luminaire for direct power LED lamp	
	LED lamp – external converter	
	Luminaire for direct power LED lamp + LED lamp external converter	
	Test setup	

Table 18. Safety Inspection of Luminaire for Converter External LED and Direct Power LED Lamp

Safety product combination	Power direct LED lamp	
	Luminaire for LED lamp – external converter	
	Luminaire for LED lamp – external converter + Power direct LED lamp	
	Test Setup	

were damaged serious safety problems occurred, as shown in Table 19. On the other hand, the power direct-type LED lamp in connection method 1 can ensure safety without any problem such as fire, electric shock, burns even when used with different luminaires and lamps. Furthermore, to prevent a decrease in energy efficiency due to excessively luminous flux, it is necessary to revise the relevant stan-

dards to a suitable level. The standards are proposed in Table 20.

In other words, it is necessary to redefine relevant standards to use safe products, and the suggested connection method is shown in Table 21.

Further research will be required in the future to evaluate the safety and performance of the power direct type of luminaire and lamp.

Table 19. Cross-Risk Analysis Table

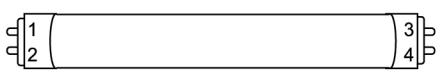
	Power direct LED lamp	LED lamp built-in converter	LED lamp-external converter	Fluorescent lamp
Luminaire for power direct LED lamp		Risk ↑	Risk ↑	Risk ↑
Luminaire for fluorescent lamp	Risk ↓		Risk ↓	
Luminaire for LED lamp-external converter	Risk ↓	Risk ↓		Risk ↓

Table 20. Proposed Safety Standards

Standard	Unit	FPL 36 W LED Lamp	FPL 55 W LED Lamp
KC10025	lm	2202 (85 % of KS standard)	3400 (85 % of KS standard)
Proposed standard	lm	1900 (74 % of KS standard)	3200 (80 % of KS standard)

Table 21. Direct Power LED Lamp Power Supply Connection Method

Double Cap LED Lamp		Cap
Power	Dummy	
1, 2 or 1, 4	2, 4 or 2, 3	G13, G5
2, 3 or 2, 4	1, 4 or 1, 3	



ACKNOWLEDGEMENT

This research was funded and supported by the Ministry of Trade through the Industry and Energy’s safety certification capability enhancement project (establishment of consumer product safety technology foundation).

REFERENCES

1. IEC60901: Single-capped fluorescent lamps – Performance specifications, 2011.
2. KC10025: LED Lamp for Fluorescent Lamp Retrofit – Internal converter type, 2014.
3. Go JJ, Kim CH. A Study on the Optical Characteristics of LED Lamp as Alternative Type of FPL Lamp. Journal of the Korean Institute of Illuminating and Electrical Installation Engineers. 2015, V29, #10, pp. 1–6.
4. KS C7601: Fluorescent lamps for general lighting service, 2009.



Jin-Tai Kim,

is the Director of Institute of Electrical and Electronics Research, Korea Testing & Research Institute, Evaluator at Korea Laboratory Accreditation Scheme (KOLAS), IECEE Technical

Assessor, and he is involved in doctoral course of plasma bio display at Kwangwoon University



Chung-hyeok Kim,

Professor, Ingenium College of Engineering, Kwangwoon University, Council member, The Korean Institute of Electrical and Electronic Material Engineers