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The Impact of Stabilization Time on Lumen and Electrical Power in LED Tube Lamp Testing

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***Abstract* - In 2022, the Indonesian Government issued a policy regarding Minimum Energy Performance Standards (MEPS) and energy-saving mark labels for Light Emitting Diode (LED) lamps. Therefore, testing laboratories or lamp manufacturers should know that the stabilization time will affect the test results. LED lumen changes rapidly during the first 30 minutes, so taking data earlier during the test may lead to different test results. The results also show that the lumen fluctuation will be lower when the run time is 45 minutes or more. Stabilization time is essential when measuring LED tube lights, so a stabilization time of 45 minutes is the most effective for data collection.**

Keywords: Light-Emitting Diode, Lumen, Electrical Power, Stabilization Time, Light Spectrum.

I. INTRODUCTION

With the depletion of natural resources, energy issues have become a global challenge. By 2021, 30% of global energy consumption and 27% of total greenhouse gas (GHG) emissions will come from the building sector [1], while energy consumption in the building sector in Indonesia is 23%[2]. Light-emitting diode (LED) technology is compared to conventional lighting technologies such as fluorescent lamps, incandescent lamps, and halogen lamps. Lighting systems with Light Emitting Diode (LED) technology are much simpler to integrate with smart controls to become intelligent systems in homes, offices, and other buildings. LED technology offers better durability and efficiency, so the sector has transitioned to LED technology over the past decade. Governments worldwide are acting fast to move away from inefficient lights through performance standards, labeling, and incentive programs, such as in Europe, where the transition to LEDs began over a decade ago[3]–[8].

The spectrum of an LED spreads the luminance emitted by a single color, such as red, green, yellow, or blue, over a wider spectrum. It is recent trends in LED that produce white light, involving the use of a mixture of blue LED with some phosphors. Of the visible wavelengths, as shown in Figure 1, the peak wavelength range is 455-490 nm; there are other wavelengths, including green 515-570 nm, yellow 570-600 nm, and red 625-720 nm [9].

Table 1: Efficacy and lifetime of lamps by lamp type

Light source	Efficacy (lm/W)	Lifetime (Hours)	Reference
Incandescent	10 -18	1000	[5], [7]
Halogen	15 -20	8400	
Compact fluorescent(CFL)	35 -60	12000	
Linear fluorescent	50 -100	25000	
Cool white LED >4000K	60 - > 120	50000	
Warm white LED <4000K	< 100	50000	

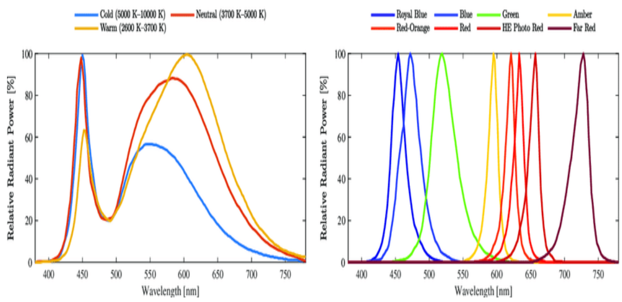

Figure 1: Wavelength of led spectrum

The European Union recently updated its Regulations under the Eco design Directive and the Restriction of Hazardous Substances Directive, aiming to phase out almost all fluorescent lig hting by 2023. In addition, 16 Southern African Development Community (SADC) countries have agreed on harmonized lighting standards that will shift the market to LEDs shortly. In addition, six East African countries under the East African Community (EAC) have implemented lighting regulations that will gradually phase out fluorescent lights. Similar measures are also being introduced in countries in Southeast Asia[3].The Ministry of Energy and Mineral Resources (MEMR) in 2022 issued a policy regarding Minimum Energy Performance Standards (SKEM) and energy-saving labels for LED lamps as stated in the Minister of Energy and Mineral Resources Decree No. 135.K/EK.07/DJE/2022. The Indonesian Government's policy on SKEM is expected to be one of the strategies and efforts to

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provide opportunities for local products to gain a more significant market share. The increase in product quality obtained by domestic LED lamp factories can increase the market for LED lamps with higher energy efficiency. The Decree of the Minister of Energy and Mineral Resources Number 135.K/EK.07/DJE/2022 states that the stabilization time is the time the lamp is stable with a limit of 0.5% relative difference in lumen and electrical power (Watt) if up to 150 minutes the lamp is not stable then the measurement can be started [10]. This research will be conducted on LED lamps of the Tube Lamp (TL) type with a total of 18 samples with a duration of 150 minutes per lamp with a data collection time interval of 15 minutes so that from this research, the most accurate stabilization time is obtained and the most efficient stabilization time in terms of time and test results.

II. METHODOLOGHY

2.1 Testing Samples

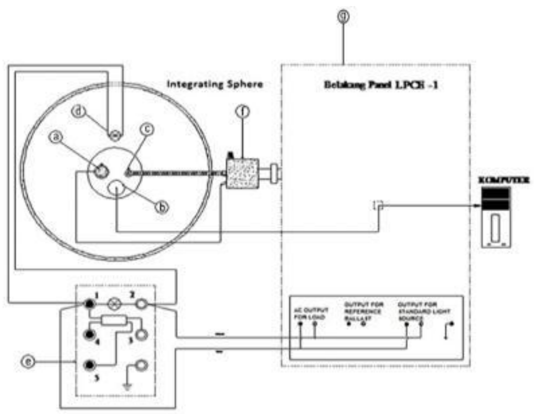
The number of lamp samples used in the test totaled 18 pieces of 9 different types with power specifications (Watt) from 8 to 18 Watt, summarised in table 2 below.

Table 2: Specification of Lamp

Code	Specification	Code	Specification
1	>70 lm/W; 220V; 16W; 6500K	10	220V; 9W; 6500K
2	>70 lm/W; 220V; 16W; 6500K	11	800lm; 220V; 70mA; 8W; 6500K
3	2100lm; 220V; 18W; 6500K; CRI>70	12	800lm; 220V; 70mA; 8W; 6500K
4	2100lm; 220V; 18W; 6500K; CRI>70	13	1600lm; 220V; 1300mA; 16W; 6500K
5	1800lm; 220V; 18W; 6000K	14	1600lm; 220V; 1300mA; 16W; 6500K
6	1800lm; 220V; 18W; 6000K	15	1600lm; 70mA; 220V; 14.5W; 6500K; CRI 80
7	220V; 9W; 3000K	16	1600lm; 70mA; 220V; 14.5W; 6500K; CRI 80
8	220V; 9W; 3000K	17	2100 lm; 220V; 18 W; 6500K; CRI 80
9	220V; 9W; 6500K	18	2100 220V; 18 W; 6500K; CRI 80

2.2 Testing equipment

This test uses an Integrating Sphere tool with the LMS-5000 type with an inner diameter of 1.5 meters and a lumen measurement range of 0.1 to 1,999,900 lm. As for the parameters that can be measured, such as Chromaticity Coordinates, Color Correlated Temperature (CCT), Peak Wavelength, Dominant Wavelength, Color Rendering Index (CRI), Luminous Flux (Lumen)and electrical parameters such as Voltage (Volt), Current (A), Power (Watt), and Power Factor (Cos φ). The LMS-5000 circuit is shown in Figure 2 below:



(a)

(b)

Figure 2: (a) integrating sphere circuit, (b) integrating sphere

Picture Description: (a) Photometer Sensor (b) Thermocouple Sensor (c) Optical Fibre (d) Measured Lamp (e) Lamp Terminal Box (f) Optical Path Converter (g) LPCE Panel (Measuring Instrument Cabinet).

In this study, lamp performance testing was carried out using the Integrating Sphere LMS5000 to obtain data on luminous flux / intense light (lumens) and electrical power (Watt), which will be analyzed in the discussion section. The test procedure is based on the Minister of Energy and Mineral Resources Decree Number 135.K/EK.07/DJE/2022, which adopts part of SNI IEC 62612: 2016. Eighteen samples were

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tested, each for 150 minutes, with data collection intervals per 15 minutes, so 10 data were obtained per lamp. The selection of a duration of 150 minutes aims to see the stability of the lumen or light strength of the lamp after it is turned on. The test conditioning in this study was carried out with an input voltage of 220 ± 0.5% V with a frequency of 50 ± 1% Hz. Conducted at an ambient air temperature of 25 ± 1 ° C with a maximum relative humidity of 65%.

2.3 Analysis of test results

This study will analyze the test results of the light intensity (lumen) and electrical power (Watt) against the test stabilization time. The 18 samples will be presented in the form of a graph to see the most effective time of testing lights in a stable state with a relative difference for the test results of the maximum and minimum values on lumen and electrical power (Watt) of less than 0.5% seen from the relative difference of the previous minute, In contrast, the calculation of the relative difference value of lumen and Watt uses the following formula [11]:

$$\Delta_L = \Delta_P = \frac{L = P\ (t_{n-1}) - \mathrm{L} = \mathrm{P}(t_n)}{L = P\ (t_{n-1})} \times 100 \qquad (1)$$

Where Δ is the relative difference (%), L is Lumen, P is Watt, t_n= minutes of measurement between two consecutive - events. The thermal stabilization time defined as obtained shall not exceed the following limitations:

$$\Delta_{L(t_n)} = \Delta_{P(t_n)} \leq \mathrm{c}$$

Where c is the predefined tolerance limit for the difference between lumen value and electrical power, c is selected as 0.5%; when the condition is fulfilled, the lamp time is considered steady.

III. RESULTS AND DISCUSSIONS

3.1 Light Intensity (Lumen) against Stabilisation Time

Looking at Figure 3, when the stabilization time above 30 minutes tends to be stable, for example, in sample 14, when the 15th minute with a lumen value of 1578.1 when compared to the relative difference equation with the 30th minute with a lumen value of 1582.1, the result is 0, 25 % then the 30th minute compared with the results of the lumen of the 45th minute then obtained a difference of 1.25% and began to stabilize after the 45th minute with a difference with the 60th minute of 0.11% and getting smaller again in the next minute of 0.10 at the 60th minute, 0.08 in the 75th minute, up to a value of 0.03 in the 135th minute.

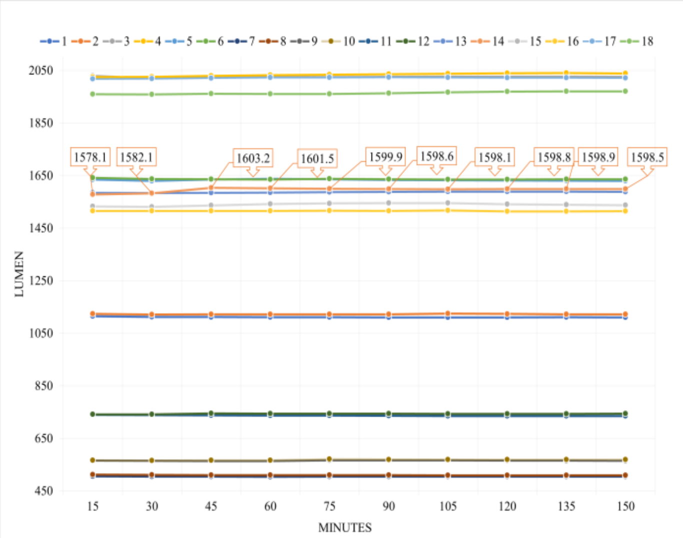

Figure 3: Light Intensity (Lumen) against Stabilisation Time

From Figure 4, it can be seen that the average relative difference in lumen values will get smaller with increasing stabilization time. However, some samples experience an increase in value at the next minute but will return to trim in the next minute. The smallest value is in the 135th minute and above, with the fastest time according to the 0.5% threshold, the relative difference at 45 minutes.

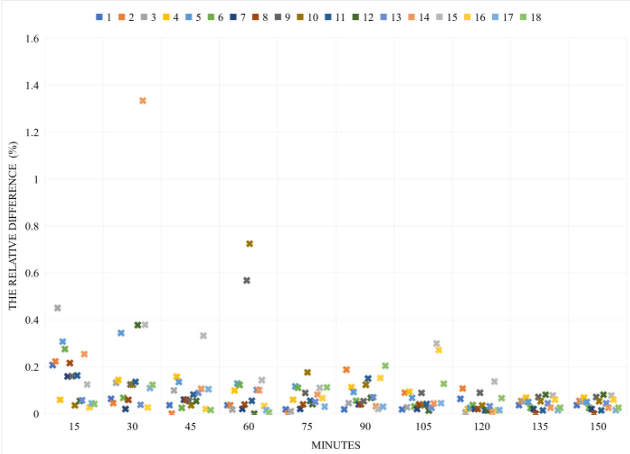

Figure 4: The Relative Difference (lumen)

3.2 Power (Watts) against Stabilisation Time

Looking at Figure 5, when the stabilization time is above 15 minutes, it will be stable except for samples 6 and 18, where electric power is stable. When the stabilization time is above 30 minutes, for example, sample 18 when the 15th minute with an electric power value of 17.5 when compared to the relative difference equation with the 30th minute with an electric power value of 17.6 then the results obtained 0.57% then the 30th minute compared to the results of the 45th-minute electric power then obtained a difference of 0% as well as the next minute.

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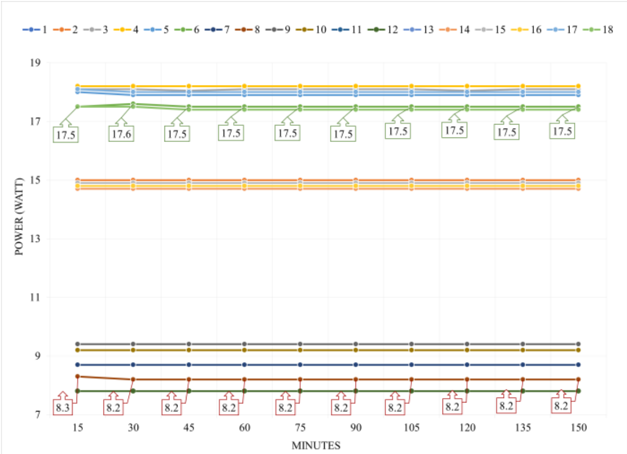

Figure 5: Light Intensity (Lumen) against Stabilisation Time

It can be seen from Figure 6that the relative difference in the electrical power value of all samples is at 45 minutes and above and the best value is at 135 minutes and above, while the relative difference and within the threshold of 0.5% with the fastest time is at 45 minutes.

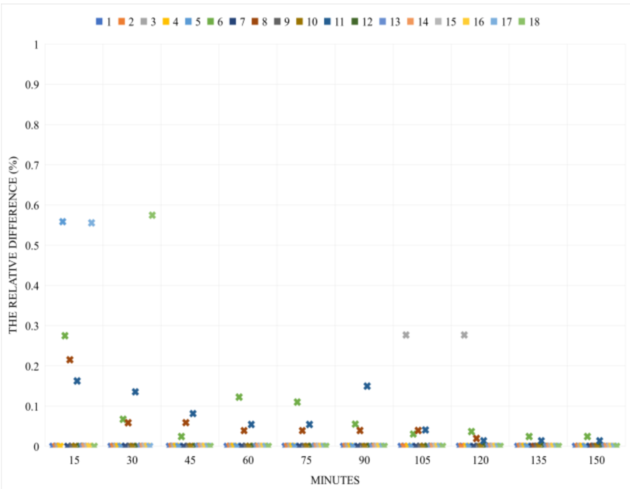

Figure 6: The Relative Difference (lumen)

3.3 Light spectrum of LED

This study found that white light or >6000 K or dominant wavelength is between 445-496 nm while yellow light (warm white) or >3000 K is between 584 to 595 nm.

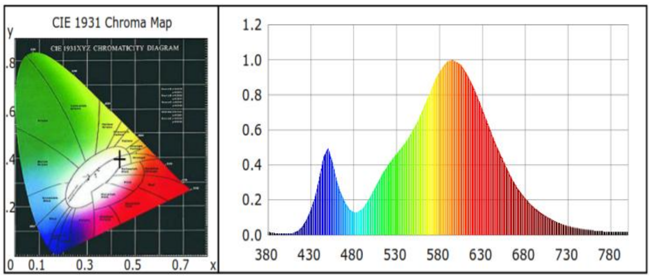

Figure 7: Typical 3000K LED spectrum

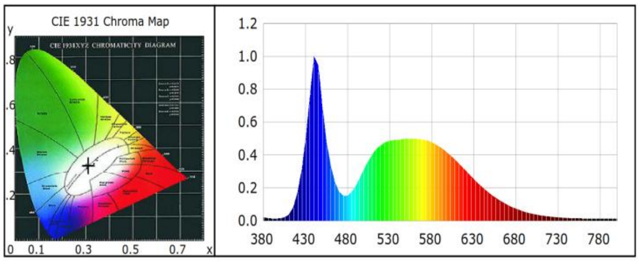

Figure 8: Typical 6500K LED spectrum

IV. CONCLUSION

From testing LED tube lights, the following results were obtained: in Light Flux or light power (Lumen) all lamps are stable within tolerance c at 75 minutes and above, the lumen is stable with a relative difference value below 0.2% at 120 minutes and above, however, if seen in Figure 4 at minute 60 two lamps cross the c limit but after 60 minutes the lamp will return to the tolerance limit at minute 75 so it is concluded that the fastest stability time and still within the c tolerance range of 0.5% is minute 45. In terms of Power (Watt), all lamps are stable and still within the tolerance c from minutes to ≥ 45, so it is concluded that the fastest stability time and still within the tolerance c of 0.5% is minute 45. The above results show that the most effective time and lamp stability is at minute 45. This study found that white light or > 6500 K wavelength or dominant wavelength between 445-496 nm while yellow light (warm white) or > 3000 K between 584 to 595 nm.

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