THE PERFORMANCE EVALUATIONS OF LOCALLY AVAILABLE FLUORESCENT BALLAST / LAMP SYSTEMS

J. C. EKEH and I. U. OKOROIGWE
Department of Electrical And Electronics Engineering
Ambrose Alli University Ekpoma-Nigeria.

ABSTRACT

The electrical and photometric characteristics of locally available 20W and 40W compact energy saving fluorescent lamps with a number of core – coil ballasts have been compared under the same laboratory conditions. Particular attention was paid to the active, reactive power consumption, power factor, and watt per ampere under varying voltage levels. A total of forty – five ballast / lamp combinations were involved in the study. The study revealed that for the locally available samples of 20W ballast/lamp system tested, the Newclime/lamptan fixture recorded the best starting characteristics. Its watt, power factor, var., and watt per ampere were respectively 18W, 0.41, 39.86 var., and 66.69. This was followed by Newcline/EPI and Sartra /Jecon combination.

For the twenty-five samples of 40W ballast/lamp combinations, it was found that Philips/Maspion fixture showed a remarkable starting characteristics, with input starting voltage of 159V followed by Philips/ Osram system with 164V and Philips/SiBalec, 166V.

The result of the study also revealed that the 40W ballast/lamp energy saving systems require lower rms starting voltage, result in lower input currents, higher power factor, higher watt per ampere, better luminaries characteristics, and lower Var consumption. These qualities compared favourably with the 20W ballast/ lamp combinations.

The results of the experimental data obtained from this study will be of importance to designers, Engineers and Architects involved with the lighting design and specification process.

LIST OF SYMBOLS AND ABBREVIATIONS

V	volt, voltmeter
A	Ammeter, Input line current
V_L	Line voltage
V_B	Ballast voltage drop
V_f	Filament voltage
W	watt
VAR	volt Ampere Reactive
W/A	watts per Ampere
θ	Deflection
EM	Electromagnetic
Hz	Hertz
p.f	Power factor
kVA	Kilo Volt Ampere
r.m.s	root mean square
a.c.	alternating current
D.C.	direct current

1.0 INTRODUCTION

The primary purpose of the lighting system is to convert electrical energy into useful light in a given enviroment. Lighting quality, visual comfort and overall system cost are department on the types of lighting system employed. Therefore, a number of brand of lighting of systems are available.

Fluorescent lamp fittings are becoming popular in residential homes and commercial outfits. The proliferation of fluorescent lighting system components has complicated the task of specifying lighting systems but has also provided designers with the flexibility to optimize lighting layouts in a way not previously possible.

A number of photometric data significantly affect the quality and uniformity of the illuminant distribution in a given task requirement.

In this paper, the electrical and photometric characteristics of lamp/ballast/ fixture combination is reported. The electrical parameters of interest are line voltage, voltage drop across the ballast, filament voltage and current. Equally important are the real power consumed, power factor, reactive power, and watt per ampere.

The experimental data and calculations obtained from the study will be of importance to designers, engineers, and architects involved with the task of lighting design and specification process.

It also provides the end users with the important parameters that should be considered in selecting a lamp / ballast/fixture combinations.

2.0 EXPERIMENTAL METHODS AND APPARATII

In this study we examined ten different lamps, nine ballast and two fixture types. The lamps and ballast represent the range of performance and efficiency encountered in typical commercial applications.

The base case ballast/lamp system consisted of standard 20 watts and 40 watts ballast/lamps. Tables 1 and 2 list the ballast specification, which includes: Rated voltage, Current, Power, Power factor and Frequency, while tables 3 and 4 show the specifications of fluorescent lamps examined. The ballast and lamps samples were purchased from manufacturers through distributors and retail stores in Ekpoma and Benin City, in Edo State.

The 20W and 40W ballast examined were: Newclime, Sartra, Hupe, Triangle and Philips. The fluorescent lamps include; Philips, SiBalec, EPI, Lamptan, Jecon, for 20W category and Philips, SiBalec, Osram, C.E., Maspion for 40W class.

A total of forty – five different ballast/lamp combinations were possible. Each ballast/lamp combination is identified with a two – letter designation. The first letter signifies the ballast types and the second letter refers to the fluorescent lamp types. It should be stated clear at this juncture that the subject of component qualification, incoming quality control testing, manufacturing systems, documentation, configuration control, and quality testing, is beyond the scope of this study. It is, however, sufficient to mention that these items because they are vital if the design is to be produced in a manner calculated to meet the specification and to produce a quality reliable product. Quality is designed and manufactured into a product and never tested into a product.

3.0 TEST PROCEDURES

One experiment each was conducted for 20W ballast/lamp/fixture and 40W ballast/lamp/fixture. The apparatii for this experiment includes a variac transformer, an electronic wattmeter (EW 60 Model), two digital meters (Voltcraft M 650B Model) ballast types, and fluorescent lamps. The circuit diagram for the measurement is shown in figure 1.

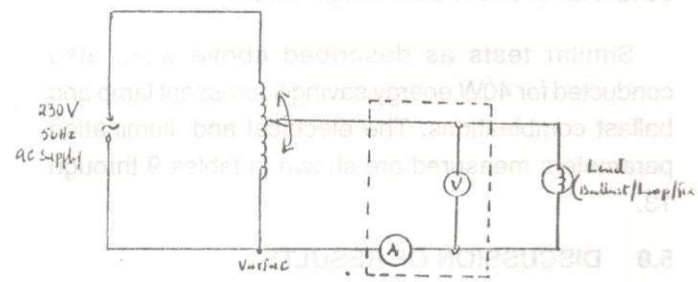

Figure 1 Experimental set up

The variac transformer on the input side is used to vary supply voltage to any desired value. Once a voltage value is set, the electronic wattmater model EW 604 calibrated to measure the electrical unit of deflection is read with the voltage factor and current factor noted. The load is made up of the ballast/lamp/fixture.

The sample size consisted of 45 ballast/lamp/fixture combinations comprising of 9 ballast and 10 lamps for 20W fittings. The breakdown consists of 4 ballast and 5 lamps of 20W category and 5 ballast, 5 lamps of 40W class. A 100 hours 'burn-in' period at rated voltage was applied prior to testing in all cases. The testing cycle consists of varying the applied line to ground potential from starting input voltage up to 280 voltage without getting lamps destroyed and in incremental steps of 20 volts.

This procedure constituted one complete cycle. All ballast/lamp/fixture load were subjected to two full voltage cycles.

Reading of all electrical and illumination parameters of interest were taken and recorded at the base point and at each incremental step during cycling. The characteristics measured were voltage across the ballast, filament voltage, that is, voltage across the lamp terminals, and electronic wattmeter deflection, voltage factor, and current factor.

4.0 EXPERIMENTAL RESULTS

The result of applying the methodology to the ballast/lamp/fixture combinations examined are summarized in tables 5 through 13. The tables 5 through 8 summarized the measurement that were taken at starting voltage, 200, 220, 230, 240, 260, 280, volts at laboratory conditions (standard pressure and temperature) using various combinations of 20W ballast/lamp on the 20W single fixture.

Similar tests as described above were also conducted for 40W energy saving fluorescent lamp and ballast combinations. The electrical and illumination parameters measured are shown in tables 9 through 13.

5.0 DISCUSSION OF RESULTS

The data base for this various ballast/lamp/fixture combinations are summarized in tables 5 through 13. The functional relationship between the electrical parameters of ballast volt drop, filament voltage, lamp current, power factor, active, reactive power consumption versus voltage is very pronounced when comparing the result of the tests. Generally, increasing the line voltage increase these parameters.

The starting voltage distributions for the ballast/lamp combination examined differ. As can be seen from the tables 5 through 8, the Newclime/lampton system recorded the lowest starting voltage of 162V, followed by Newclime/EPI fixture with 164V, and Sartra/Jecon combination, 165V. At this voltage, for the Newclime/Lampan fixture, the watt, power factor, var. and watt per ampere were respectively 18W, 0.441, 39.86 Var and 66.67.

The triangle/lamptan combination tested the worst starting voltage of 205V, followed by Hupe/Jecon, 203V, Sartra/lamptan, 200V, Triangle/SiBalec and Triangle/Jecon 197V.

However, Hupe /Lamptan fixture with a starting voltage of 192V recorded the highest watt consumption of 25.5W and power factor of 0.49, watt per ampere of 44.44 and Var of 45.3.

The effect of ballast voltage drop and the filament voltage change for the selected lamp/ballast fixture combinations are most apparent. Increasing the line voltages increase both the ballast voltage drop and filament voltage for all the combinations. The Newclime/Lamptan and Sartra/Jecon measured the lowest ballast voltage drops of 136V and filament voltage of 210V, the Hupe/Jecon and triangle/lamptan systems registered the highest value of ballast voltage drop of 181V with filament voltage of 254 and 253V respectively.

The second category of 40 watts electromagnetic ballast/lamp/fixture combinations are shown in tables 9 through 13. The electrical characteristics measured and calculated were the same as that of the 20W ballast/lamp systems. The ballast voltage drop, lamp volt, current, watt, power factor, and watt per ampere for all the ballast/lamp combinations vary with line voltage.

As expected the electrical characteristics are substantially different from that of the 20W ballast/lamps systems. For example at 200V input voltage, the 20W Newclime/philips measured 0.38A while 40W Newclime/Philips system measured 0.30A. The corresponding wattage are 22W and 30W. The reactive powers were 72.75 Var and 51.96 Var respectively.

Similarly, at 200V, 20W Newclime/SiBalec system had ballast voltage drop, lamp volt current, and wattage values of 178V, 241V, 0.38A and 21W while 40W Newcline/SiBalec system measured 150V, 26W, 0.29A and 30W respectively.

The same pattern of behaviour in all these parameters are displayed by 20W Sartra/lamp and Sartra/lamp combinations.

Generally speaking, the higher operating current will always result in lower lamp voltage values because of the negative volt – ampere characteristic of the discharge. Although not shown, increasing the ambient above the 77^{0}F reference point will also cause lamp voltage to decrease because of the increasing mercury vapour pressure within the lamp.

With respect to the starting characteristics as shown in tables 9 through 13 the 40W ballast/lamp systems did not show any significant different values in respect of the starting voltages. The Philip/Maspion combination recorded the least starting input line voltage of 159V. This value compared favourably with the value of 162V recorded by the 20W Newclime/lamptan system.

The next system is Philips/Osram combination with a starting voltage value of 164V, followed by Philips/SiBalec 166V.

It can be said categorically here that the length of the fluorescent fitting did not mean higher starting voltage.

As expected, the system power factor, using the 40W ballast/lamp systems are higher than 20W ballast/lamp combinations. For example, at 240W Hupe/Philips system had a p.f of 0.33 and watt per ampere of 78.85 while 40W Hupe/Philips recorded 0.68 and 16.33 value respectively. Also, at 240V, 20W Hupe/SiBalec system measured p. f. 0.44 and watt per ampere of 105.41. At the same voltage level, 40W Hupe/SiBalec system measured corresponding value of 0.56 and 135.48.

The relative ballast/lamp efficacy relationships with line voltage for the two systems need some comment. Both types show high lumen output values as line voltage vary from starting voltage of 200V to 280V. Higher lumen output value were observed from 40W ballast/lamp systems in comparison with 20W system for the same line voltage.

The estimated total costs of the compared systems differ. Energy is the major cost of lighting while maintenance costs are relatively small. The total average costs of the ballast/lamp combination with the 40W fixtures are consistently higher than those with the 20W fixtures. This slightly higher cost is relatively cheaper when compared with the efficiency of the 20W system.

The system p.f. characteristics deserve some comments. For a given 40W ballast/lamp system the p.f. did not change significantly with line voltages. This behaviour is similar for all of the different ballast/lamp combinations regardless of input current.

The change in reactive power consumption versus voltage is very pronounced when comparing the results of tests performed on 20W and 40W ballast/lamp system. Generally speaking, there is increase in var. loading when line voltage level increases with a reduction in reactive (Vars) compared to results obtained with 20W counterpart.

The 40W ballast/lamp energy saving systems require a lower rms voltage, results in a lower input current, a higher power factor, higher watt per ampere, better luminaries characteristics and lower var. consumption. These factors have a positive impact upon the electrical supply and lamp life.

6.0 CONCLUSIONS

A proper selection of lamps ballasts, and fixture in a fluorescent lighting installation can result in a decrease in starting voltage, low energy consumption, and better luminaries characteristics.

The experiment data described in this study has confirmed that the electrical and photometric characteristics of fluorsecent fittings vary with voltage change. The data obtained from this study will provide an important and necessary data for the study and evaluation of interior lighting systems, facilitate system selection, and enhance the overall design process.

The study has revealed that for the 20W ballast/lamp combinations, the Newclime/Lampton system exhibited the best electrical characteristics while for the 40W ballast/lamp combinations, the Philips/Maspion system was most outstanding.

Also, the study revealed that it is economically and technically advantageous to use 40W combination as against the 20W counterpart since the former require lower starting voltage, resulted in lower input current, higher power factor, watt per ampere, better luminaries characteristics, and lower var consumption.

7.0 RECOMMENDATIONS FOR FURTHER WORK:

One of the major parameter of the photometric characteristic, the lumen/metre^2 was not examined in this study due to non availability of equipment, the luxmeter. There is need for complete photometric characteristics of the system, particularly if one want to compare the performance between different ballast/lamps in different luninaries.

It is therefore recommended that further research be carried out in the area of photometric characteristics in order to determine the lumen/m^2 of each lamp/ballast system.

8.0 REFERENCES

1. **N. F. Neil's** "Specifying Energy Efficiency in New Fluorescent Fixture", IEEE IAS, Annual meeting, Pennsylvania Oct. 2.- 7, 1988, pp. 1870 – 1877.

2. **R. R. Verderber, O. Morse and F. M. Rubinstein,** "Performance of Electronic Ballast and Controls with 34 and 40 watt F40 fluorescent Lamps", IEEE IAS, Annual meeting, Pennsylvania Oct. 2 –7 1988. Pp. 1825 – 1834.

3. **W. R. Alling,** "Important Design parameters for solid state Ballast", IEEE IAS, Annual meeting, Georgia, Oct. 18 – 23, 1987. Pp. 1811 –1816.

4. **M. J. Siminovitch, F. M. Rubinstein, R. R. Verderber, and T. A. Clark",** The effects of IEEE IAS Annual meeting, Colorado, September 28 – October 3, 1986, Pp. 1680 – 1684.

5. **S. A. Kalinowsky and J. J. Martello,** "Electrical and Illumiation characteristics of energy saving fluorescent as a function of potential", IEEE IAS Annual meeting, Georgia, October 18 – 23, 1987. Pp. 1795 – 1802.

6. **E. E. Hammer,** "Starting Voltage Characteristics of 40W Biaxial fluorescent lamps", IEEE IAS Annual meeting, Pennsylvania, October 2 – 7 , 1988, Pp. 1836 – 1841.

7. **E. E. Hammer** " Effects of Ambient temperature on the performance of bent tube fluorescent Lamps" IEEE IAS, Annual meeting Georgia, October 18 –23, 1987, Pp. 1715 -1783.

8. **E. E. Hammer** "Effect of changing Line voltage with various fluorescent systems" IEEE IAS Annual meeting, Colorado, September 28 – October 3, 1986, Pp. 1674 – 1679.

9. **F. Rubinstein, T. Clark., M. Siminovitch, and R. Verderber,** "The effect of lighting system components on lighting, Energy use, and life – cycle cost", IEEE IAS Annual meeting, Coloorado, September 28 –October 3, 1986, Pp. 1685 – 1689.

10. **D. R. Zatyko,** "Economic Advantage of Cathode heat cut off in fluorescent lighting systems", IEEE IAS, Annual meeting, Colorado, September 28 – October 3, 1986, Pp. 1690-1696.

11. McGraw – Hill Encyclopedia of Science and Technology, pp. 7,210 – 212.

12. **M. Neidle,** "Electrical Installation Technology", 2nd Edition, Butterworths, 1975, pp. 279 – 302.

13. **D. G. Fink and H. W. Beaty** (editors), "Standard handbook for Electrical Engineers", 11th edition, McGraw- Hill, New York, 1978, Pp. 2215 – 2220.

14. **S. L. Uppal,** "Electrical Power", khanna, New Delhi, 1980, pp. 1522 – 1587.

15. **J. C. Ekeh & L. I. Agbogwu,** "Performance Evaluation of locally made 60W, 220 /240V incandescent domestic lighting fittings ", Journal of Engineering Science and Applications (JESA), Vol.1,No.1 May 1999, PP.71-79.

TABLE 1 DETAILED SPECIFICATIONS OF AVAILABLE 20W EM BALLAST TESTED

S/No.	Ballast Type	Rated Voltage (Volts)	Rated Current (Amperes)	Rated Power (Watts)	Rated power factor	Frequency (Hertz)	Cost (Naira)
1	Newclime, Germany	240	0.43	20	0.45	50	200.00
2	Sartra, London	240	0.37	20	0.36	50	200.00
3	Hupe, Germany	220	-	20	0.50	50	200.00
4	Triangle,China	220	0.31	20	-	50	150.00

TABLE 2: DETAILED SPECIFICATIONS OF AVAILABLE 40W EM BALLAST TESTED

S/No.	Ballast Type	Rated Voltage (Volts)	Rated Current (Amperes)	Rated Power (Watts)	Rated power factor	Frequency (Hertz)	Cost (Naira)
1	Newclime, Germany	240	0.43	40	0.45	50	200.00
2	Sartra, London	240	0.43	40	0.45	50	180.00
3	Hupe, Germany	220	-	40	0.50	50	200.00
4	Triangle, China	220	0.43	40	-	50	150.00
5	Philips, Holland	220	0.43	40	0.45	50	200.00

TABLE 3: DETAILED SPECIFICATIONS OF AVAILABLE 20W FLOURESCENT LAMPS TESTED

S/No.	Lamp Type	Rated Voltage (Volts)	Rated Power (Watts)	Frequency (Hertz)	Cost (Naira)
1	Philips,Holland	220/240	18	50	180.00
2	SiBalec, Indonesia	220	18	50	100.00
3	EPI	220	20	50	100.00
4	Lamptan	220	20	50	100.00
5	Jecon,Nigeria	220	20	50	100.00

TABLE 4: DETAILED SPECIFICATIONS OF AVAILABLE 40W FLOURESCENT LAMPS TESTED

S/No.	Lamp Type	Rated Voltage (Volts)	Rated Power (Watts)	Frequency (Hertz)	Cost (Naira)
1	Philips,France	220	36	50	190.00
2	SiBalec,Indonesia	220	36	50	120.00
3	C.E,Taiwan	220	40	50	120.00
4	Osram,Germany	220	36	50	130.00
5	Maspion,Indonesia	220	36	50	120.00

TABLE 5: CHARACTERISTICS OF 20W NEWCLIME EM BALLAST 0PERATING ON 20W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP COMBINATION BALLAST TYPE	LAMP TYPE	V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
1	Newclime	Philips	166	143	211	0.29	0.036	18	0.37	44.65	62.07
			200	180	245	0.38	0.044	22	0.29	72.75	57.89
			220	203	266	0.43	0.056	28	0.30	90.36	65.12
			230	212	273	0.46	0.062	31	0.29	101.16	67.39
			240	225	285	0.50	0.070	35	0.29	141.84	70.00
			260	245	303	0.58	0.084	42	0.28	114.83	72.41
			280	263	318	0.69	0.116	58	0.30	184.29	84.06
2	Newclime	SiBalec	193	172	234	0.36	0.040	20	0.29	66.54	55.55
			200	178	241	0.38	0.042	21	0.28	73.04	55.26
			220	202	263	0.43	0.056	28	0.30	90.36	65.12
			230	213	273	0.46	0.062	31	0.29	101.16	67.39
			240	221	280	0.49	0.070	35	0.30	112.18	71.43
			260	243	300	0.57	0.084	42	0.28	142.12	73.68
			280	263	318	0.68	0.110	55	0.29	182.28	80.88
3	Newclime	EPI	164	138	210	0.28	0.042	21	0.46	40.84	75.00
			200	180	249	0.38	0.056	28	0.37	70.65	73.68
			220	204	271	0.44	0.062	31	0.32	91.70	70.45
			230	211	277	0.46	0.072	36	0.34	99.49	78.26
			240	222	288	0.49	0.080	40	0.34	110.59	81.63
			260	243	307	0.57	0.098	49	0.33	139.87	85.96
			280	262	323	0.67	0.120	60	0.32	177.75	89.55
4	Newclime	Lamptan	162	136	209	0.27	0.036	18	0.41	39.86	66.67
			200	180	242	0.37	0.048	24	0.32	70.00	64.86
			220	200	264	0.43	0.058	29	0.31	90.05	67.44
			230	210	273	0.46	0.062	31	0.29	101.16	67.39
			240	223	287	0.49	0.076	38	0.32	111.29	77.55
			260	245	310	0.58	0.096	48	0.32	142.96	82.76
			280	265	327	0.69	0.116	58	0.30	184.29	84.06
5	Newclime	Jecon	186	164	228	0.34	0.042	21	0.33	59.65	61.76
			200	182	244	0.38	0.050	25	0.33	71.77	65.79
			220	202	262	0.43	0.060	30	0.32	89.63	69.77
			230	212	271	0.47	0.064	32	0.30	103.26	68.09
			240	222	280	0.49	0.076	38	0.32	111.29	77.55
			260	242	297	0.57	0.096	48	0.32	140.21	84.21
			280	260	311	0.67	0.116	58	0.31	178.41	86.57

DEFINITIONS:

V_L	LINE VOLTAGE
V_B	BALLAST VOLTAGE DROP
V_F	FILAMENT VOLTAGE DROP
A	LINE CURRENT
θ	WATTMETER DEFLECTION
W	INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F.	BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
VAR	REACTIVE POWER = V_L x A x Sin ϕ
W/A	WATT PER AMPERE

TABLE 6: CHARACTERISTICS OF 20W SARTRA EM BALLAST OPERATING ON 20W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP COMBINATION		V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
	BALLAST TYPE	LAMP TYPE									
1	Sartra	Philips	185	161	232	0.25	0.030	15	0.32	43.75	60.00
			200	176	245	0.27	0.040	20	0.37	50.16	74.07
			220	199	266	0.31	0.042	21	0.31	64.89	67.74
			230	213	279	0.34	0.050	25	0.32	74.10	73.53
			240	220	285	0.36	0.056	28	0.32	81.74	77.78
			260	241	304	0.41	0.062	31	0.29	101.99	75.61
			280	262	323	0.49	0.080	40	0.29	131.24	81.63
2	Sartra	SiBalec	191	167	244	0.25	0.036	18	0.38	44.23	72.0
			200	176	246	0.27	0.040	20	0.37	50.16	74.07
			220	198	266	0.31	0.042	21	0.31	64.89	67.74
			230	210	275	0.33	0.050	25	0.33	71.66	75.76
			240	220	283	0.36	0.056	28	0.32	81.74	77.77
			260	241	302	0.41	0.062	31	0.29	101.99	75.61
			280	261	320	0.49	0.080	40	0.29	131.24	81.63
3	Sartra	EPI	169	143	217	0.22	0.030	15	0.40	34.02	68.18
			200	178	249	0.27	0.040	20	0.37	50.16	74.07
			220	199	269	0.31	0.044	22	0.32	64.55	70.97
			230	209	278	0.33	0.056	28	0.37	70.55	84.85
			240	220	287	0.36	0.060	30	0.35	80.94	83.33
			260	240	306	0.41	0.068	34	0.32	101.03	82.93
			280	261	326	0.49	0.090	45	0.33	129.61	91.84
4	Sartra	Lamptan	200	173	252	0.26	0.042	21	0.40	47.57	80.77
			220	194	272	0.30	0.050	25	0.38	61.08	83.33
			230	209	286	0.33	0.056	28	0.37	70.45	84.85
			240	219	293	0.35	0.060	30	0.36	78.46	85.71
			260	242	312	0.41	0.070	35	0.33	100.69	85.37
			280	262	328	0.49	0.084	42	0.31	130.61	85.71
5	Sartra	Jecon	165	136	209	0.20	0.030	15	0.43	29.39	75.00
			200	176	244	0.27	0.042	21	0.39	49.75	77.78
			220	199	265	0.31	0.048	24	0.35	63.84	77.42
			230	211	276	0.33	0.056	28	0.37	70.55	84.85
			240	220	284	0.35	0.058	29	0.35	78.69	82.86
			260	241	303	0.41	0.064	32	0.30	101.68	78.05
			280	261	320	0.48	0.080	40	0.30	128.31	83.33

DEFINITIONS:

- V_L — LINE VOLTAGE
- V_B — BALLAST VOLTAGE DROP
- V_F — FILAMENT VOLTAGE DROP
- A — LINE CURRENT
- θ — WATTMETER DEFLECTION
- W — INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
- P.F. — BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
- VAR — REACTIVE POWER = $V_L \times A \times \sin\phi$
- W/A — WATT PER AMPERE

TABLE 7: CHARACTERISTICS OF 20W HUPE EM BALLAST 0PERATING ON 20W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP BALLAST TYPE	COMBINATION LAMP TYPE	V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
1	Hupe	Philips	182	161	239	0.25	0.034	17	0.37	42.20	68.00
			200	188	268	0.28	0.042	21	0.38	51.91	75.00
			220	202	280	0.32	0.048	24	0.34	66.08	75.00
			230	221	295	0.36	0.059	29.5	0.36	77.37	81.94
			240	248	331	0.38	0.060	30	0.33	86.12	78.95
			260	263	334	0.46	0.078	39	0.33	113.06	84.78
			280	271	341	0.52	0.098	49	0.34	137.11	94.23
2	Hupe	SiBalec	192	168	240	0.26	0.042	21	0.42	45.29	80.77
			200	179	250	0.28	0.048	24	0.13	50.60	85.71
			220	199	266	0.34	0.059	29.5	0.39	68.74	86.76
			230	224	291	0.36	0.064	32	0.39	76.37	88.89
			240	230	294	0.37	0.078	39	0.44	79.78	105.41
			260	248	311	0.42	0.078	39	0.36	102.00	92.86
			280	272	332	0.49	0.100	50	0.36	127.76	102.04
3	Hupe	EPI	189	163	241	0.28	0.040	20	0.38	49.00	71.43
			200	177	253	0.31	0.056	28	0.45	55.32	90.32
			220	162	234	0.38	0.059	29.5	0.35	78.22	77.63
			230	214	287	0.33	0.060	30	0.40	69.72	90.91
			240	228	300	0.38	0.062	31	0.34	85.77	81.58
			260	246	316	0.44	0.082	41	0.36	106.80	93.18
			280	271	335	0.49	0.094	47	0.34	128.90	95.92
4	Hupe	Lamptan	192	174	258	0.27	0.051	25.5	0.49	45.13	94.44
			200	178	248	0.28	0.052	26.0	0.46	49.60	92.86
			220	202	278	0.34	0.064	32	0.43	67.61	94.12
			230	216	291	0.36	0.064	32	0.39	97.37	88.89
			240	228	303	0.39	0.060	30	0.32	88.68	76.92
			260	246	319	0.44	0.082	41	0.36	106.80	93.18
			280	261	324	0.49	0.100	50	0.36	127.76	102.04
5	Hupe	Jecon	203	181	254	0.26	0.042	21	0.40	48.42	80.77
			220	197	265	0.28	0.046	23	0.37	57.15	82.14
			230	212	279	0.34	0.054	27	0.35	73.39	79.41
			240	224	291	0.37	0.060	30	0.34	83.58	81.08
			260	246	311	0.46	0.080	40	0.33	112.71	86.96
			280	261	323	0.57	0.118	59	0.37	148.27	103.51

DEFINITIONS:

V_L	LINE VOLTAGE
V_B	BALLAST VOLTAGE DROP
V_F	FILAMENT VOLTAGE DROP
A	LINE CURRENT
θ	WATTMETER DEFLECTION
W	INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F.	BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
VAR	REACTIVE POWER = V_L x A x Sin ϕ
W/A	WATT PER AMPERE

TABLE 8: CHARACTERISTICS OF 20W TRIANGLE EM BALLAST OPERATING ON 20W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP COMBINATION BALLAST TYPE	LAMP TYPE	V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
1	Triangle	Philips	185	158	232	0.21	0.030	15	0.39	35.84	71.43
			200	174	246	0.24	0.038	19	0.40	44.08	79.17
			220	197	265	0.28	0.040	20	0.32	58.26	71.43
			230	208	274	0.31	0.044	22	0.31	67.82	70.97
			240	219	284	0.34	0.058	29	0.36	76.27	85.29
			260	239	302	0.43	0.060	30	0.27	107.70	69.77
			280	260	321	0.54	0.116	58	0.36	141.23	107.41
2	Triangle	SiBalec	197	172	241	0.23	0.032	16	0.35	42.39	69.57
			200	175	245	0.24	0.036	18	0.38	44.50	75.00
			220	197	264	0.28	0.042	21	0.34	57.91	75.00
			230	209	274	0.31	0.050	25	0.35	66.71	80.65
			240	217	281	0.34	0.056	28	0.34	76.65	82.35
			260	239	300	0.42	0.080	40	0.37	101.61	95.24
			280	259	318	0.53	0.110	55	0.37	137.83	103.77
3	Triangle	EPI	177	148	221	0.19	0.030	15	0.47	30.10	78.95
			200	174	245	0.24	0.038	19	0.40	44.08	79.17
			220	196	266	0.29	0.044	22	0.34	59.89	75.86
			230	207	275	0.31	0.056	28	0.39	65.57	90.32
			240	217	284	0.34	0.060	30	0.36	75.89	88.24
			260	240	304	0.42	0.084	42	0.38	100.80	100.00
			280	257	320	0.53	0.120	60	0.40	135.73	113.21
4	Triangle	Lamptan	205	181	253	0.25	0.040	20	0.39	47.19	80.00
			220	197	266	0.29	0.042	21	0.38	60.24	72.41
			230	210	278	0.33	0.050	25	0.33	71.66	75.76
			240	220	288	0.36	0.060	30	0.35	81.02	83.33
			260	240	305	0.44	0.080	40	0.35	107.18	90.91
			280	256	317	0.55	0.116	58	0.38	142.66	105.45
5	Triangle	Jecon	197	168	237	0.24	0.040	20	0.42	42.84	83.33
			200	176	242	0.25	0.042	21	0.42	45.38	84.00
			220	197	261	0.29	0.050	25	0.39	58.70	86.21
			230	208	273	0.31	0.050	25	0.35	66.77	80.65
			240	217	281	0.35	0.056	28	0.33	79.20	80.00
			260	236	299	0.43	0.076	38	0.34	105.14	88.37
			280	256	313	0.54	0.104	52	0.34	141.98	96.30

DEFINITIONS:

V_L	LINE VOLTAGE
V_B	BALLAST VOLTAGE DROP
V_F	FILAMENT VOLTAGE DROP
A	LINE CURRENT
θ	WATTMETER DEFLECTION
W	INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F.	BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
VAR	REACTIVE POWER = V_L x A x Sin ϕ
W/A	WATT PER AMPERE

TABLE 9: CHARACTERISTICS OF 40W NEWCLIME EM BALLAST 0PERATING ON 40W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP BALLAST TYPE	COMBINATION LAMP TYPE	V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
1	Newclime	Philips	169	96	226	0.22	0.038	19	0.51	31.96	86.36
			200	146	267	0.30	0.060	30	0.50	51.96	100.00
			220	170	289	0.38	0.076	38	0.58	53.96	126.67
			230	183	300	0.31	0.080	40	0.56	59.02	129.03
			240	195	310	0.31	0.090	45	0.60	59.52	145.16
			260	219	330	0.39	0.102	51	0.50	87.64	130.77
			276	234	343	0.41	0.110	55	0.49	98.89	135.15
2	Newclime	SiBalec	181	125	239	0.28	0.040	20	**0.39**	46.57	71.43
			200	150	261	0.29	0.060	30	**0.52**	49.54	103.45
			220	173	284	0.30	0.078	39	0.59	53.24	130.00
			230	184	293	0.31	0.080	40	0.56	59.02	129.03
			240	197	303	0.32	0.090	45	0.59	62.24	140.63
			260	221	322	0.41	0.102	51	0.48	93.61	124.39
			270	222	330	0.41	0.110	55	0.50	96.07	134.15
3	Newclime	Osram	176	101	235	0.21	0.040	20	0.54	31.08	95.24
			200	138	266	0.25	0.060	30	0.60	40.00	120.00
			220	166	287	0.30	0.080	40	0.60	52.50	133.33
			230	182	299	0.30	0.084	42	0.61	54.74	140.00
			240	194	308	0.31	0.098	49	0.66	55.99	158.06
			260	218	327	0.39	0.102	51	0.50	87.64	130.77
			270	229	335	0.41	0.118	59	0.53	93.67	143.90
4	Newclime	C.E.	183	116	245	0.25	0.050	25	0.55	38.32	100.00
			200	138	264	0.28	0.062	31	0.55	46.64	110.71
			220	171	287	0.29	0.080	40	0.63	49.70	137.93
			230	182	295	0.30	0.082	41	0.59	55.50	136.67
			240	196	306	0.31	0.098	49	0.66	55.99	158.06
			260	220	325	0.40	0.104	52	0.50	90.07	130.00
			268	229	332	0.41	0.118	59	0.54	92.70	143.90
5	Newclime	Maspion	192	123	257	0.28	0.060	30	0.56	44.61	107.14
			200	136	267	0.29	0.062	31	0.53	49.02	106.90
			220	164	289	0.30	0.080	40	0.61	52.30	133.33
			230	178	299	0.30	0.084	42	0.61	54.74	140.00
			240	194	312	0.31	0.100	50	0.67	55.09	161.29
			260	217	331	0.38	0.110	55	0.56	82.08	144.74
			270	228	339	0.40	0.120	60	0.56	89.80	150.00

DEFINITIONS:

V_L LINE VOLTAGE
V_B BALLAST VOLTAGE DROP
V_F FILAMENT VOLTAGE DROP
A LINE CURRENT
θ WATTMETER DEFLECTION
W INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F. BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
VAR REACTIVE POWER = V_L x A x Sin ϕ
W/A WATT PER AMPERE

TABLE 10: CHARACTERISTICS OF 40W SARTRA EM BALLAST 0PERATING ON 40W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP COMBINATION		V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
	BALLAST TYPE	LAMP TYPE									
1	Sartra	Philips	185	124	243	0.25	0.050	25	0.54	38.91	100.00
			200	142	264	0.29	0.060	30	0.52	49.64	103.45
			220	167	287	0.30	0.078	39	0.59	53.24	130.00
			230	179	298	0.31	0.080	40	0.56	59.02	129.03
			240	192	309	0.31	0.090	45	0.60	59.52	145.16
			260	216	328	0.35	0.102	55	0.56	75.39	145.71
			280	241	348	0.45	0.130	65			
2	Sartra	SiBalec	189	131	248	0.30	0.060	30	0.53	48.11	100.00
			200	142	261	0.29	0.062	31	0.53	49.02	106.90
			220	169	284	0.30	0.080	40	0.61	52.50	133.33
			230	181	294	0.31	0.082	41	0.58	58.33	132.26
			240	193	304	0.31	0.090	45	0.60	59.25	145.16
			260	218	324	0.39	0.102	51	0.50	87.64	130.77
			280	241	342	0.45	0.120	60	0.48	110.80	133.33
3	Sartra	Osram	186	125	246	0.29	0.050	25	0.46	47.80	86.21
			200	140	264	0.29	0.060	30	0.52	49.64	103.45
			220	166	287	0.30	0.078	39	0.59	53.24	130.00
			230	178	298	0.31	0.080	40	0.56	59.02	129.03
			240	189	308	0.31	0.090	45	0.60	59.25	145.16
			260	215	328	0.35	0.102	51	0.56	75.37	145.71
			280	239	348	0.45	0.122	56	0.44	112.87	124.44
4	Sartra	C.E.	171	92	225	0.20	0.040	20	0.58	27.74	100.00
			200	141	262	0.23	0.060	30	0.65	34.87	130.43
			220	167	284	0.25	0.070	35	0.64	42.43	140.00
			230	179	295	0.28	0.080	40	0.62	50.47	142.86
			240	191	305	0.30	0.090	45	0.63	56.20	150.00
			260	216	325	0.35	0.105				
			280	239	345	0.42	0.120	60	0.51	101.14	142.86
5	Sartra	Maspion	187	109	245	0.26	0.050	25	0.51	41.70	96.15
			200	132	265	0.28	0.060	30	0.54	47.29	107.14
			220	161	288	0.30	0.080	40	0.61	52.50	133.33
			230	176	297	0.31	0.088	44	0.62	56.10	141.94
			240	189	308	0.31	0.100	50	0.62	55.09	161.29
			260	214	330	0.37	0.118	59	0.61	75.98	159.46
			280	235	349	0.41	1.222	61	0.53	97.25	148.78

DEFINITIONS:

V_L	LINE VOLTAGE
V_B	BALLAST VOLTAGE DROP
V_F	FILAMENT VOLTAGE DROP
A	LINE CURRENT
θ	WATTMETER DEFLECTION
W	INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F.	BALLAST/LAMP COMBINATION POWER FACTOR = W/V_LA
VAR	REACTIVE POWER = V_L x A x Sin ϕ
W/A	WATT PER AMPERE

TABLE 11: CHARACTERISTICS OF 40W HUPE EM BALLAST 0PERATING ON 40W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP BALLAST TYPE	COMBINATION LAMP TYPE	V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
1	Hupe	Philips	172	94	224	0.21	0.040	20	0.55	30.58	95.24
			200	141	262	0.21	0.060	30	0.71	29.39	142.86
			220	166	286	0.25	0.080	40	0.73	37.75	160.00
			230	179	297	0.29	0.080	40	0.60	53.37	137.93
			240	191	307	0.30	0.098	49	0.68	52.75	163.33
			260	216	327	0.40	0.118	59	0.57	85.64	147.50
			277	235	341	0.50	0.142	71	0.51	118.92	147.50
											142.00
2	Hupe	SiBalec	190	135	247	0.29	0.050	25	0.45	49.10	86.21
			200	143	260	0.29	0.060	30	0.52	49.64	103.45
			220	169	282	0.30	0.070	35	0.53	55.96	116.67
			230	181	292	0.30	0.080	40	0.58	56.22	133.33
			240	194	302	0.31	0.084	42	0.56	61.41	135.48
			260	217	320	0.40	0.112	56	0.54	87.64	140.00
			277	235	331	0.51	0.140	70	0.50	122.71	137.25
3	Hupe	Osram	178	99	234	0.21	0.040	20	0.54	31.58	95.24
			200	136	264	0.22	0.060	30	0.68	32.19	136.36
			220	164	286	0.25	0.070	35	0.64	42.43	140.00
			230	177	297	0.29	0.080	40	0.60	53.37	137.93
			240	189	307	0.30	0.090	45	0.63	56.20	150.00
			260	214	326	0.39	0.110	55	0.54	85.19	141.03
			274	231	331	0.50	0.140	70	0.51	117.77	140.00
4	Hupe	C.E.	176	99	231	0.22	0.040	20	0.52	33.15	90.91
			200	138	262	0.25	0.060	30	0.60	40.00	120.00
			220	166	285	0.29	0.078	39	0.61	50.49	134.48
			230	180	295	0.30	0.080	40	0.60	56.22	133.33
			240	193	305	0.31	0.090	45	0.60	59.24	145.16
			260	215	322	0.40	0.116	58	0.56	86.32	145.00
			274	231	331	0.50	0.140	70	0.51	117.77	140.00
5	Hupe	Maspion	177	95	233	0.21	0.040	20	0.54	31.33	95.24
			200	134	264	0.25	0.060	30	0.60	40.00	120.00
			220	162	287	0.30	0.078	39	0.59	53.24	130.00
			230	177	298	0.30	0.080	40	0.58	56.22	133.33
			240	189	308	0.31	0.090	45	0.60	59.25	145.16
			260	214	327	0.40	0.110	55	0.53	88.27	137.50
			274	230	337	0.50	0.136	68	0.50	118.93	136.00

DEFINITIONS:

- V_L LINE VOLTAGE
- V_B BALLAST VOLTAGE DROP
- V_F FILAMENT VOLTAGE DROP
- A LINE CURRENT
- θ WATTMETER DEFLECTION
- W INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
- P.F. BALLAST/LAMP COMBINATION POWER FACTOR = W/V_LA
- VAR REACTIVE POWER = $V_L \times A \times \sin\phi$
- W/A WATT PER AMPERE

TABLE 12: CHARACTERISTICS OF 40W TRIANGLE EM BALLAST 0PERATING ON 40W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP COMBINATION		V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
	BALLAST TYPE	LAMP TYPE									
1	Triangle	Philips	190	121	250	0.23	0.044	22	0.50	37.76	95.65
			200	138	260	0.22	0.050	25	0.57	36.21	113.64
			220	162	285	0.22	0.070	35	0.72	33.43	159.09
			230	174	297	0.25	0.080	40	0.70	41.31	160.00
			240	189	307	0.29	0.084	42	0.60	55.50	144.63
			260	212	339	0.31	0.104	52	0.65	61.58	167.74
			280	235	348	0.40	0.128	64	0.57	91.91	160.00
2	Triangle	SiBalec	222	178	278	0.34	0.070	35	0.46	66.87	102.94
			230	183	287	0.35	0.075	37.5	0.47	71.23	107.14
			240	192	300	0.35	0.080	40	0.48	73.86	114.29
			260	214	321	0.35	0.100	50	0.55	76.03	142.86
			280	235	339	0.40	0.130	65	0.58	91.21	162.50
3	Triangle	Osram	204	148	262	0.28	0.060	30	0.53	48.61	107.14
			220	166	281	0.25	0.070	35	0.64	42.43	140.00
			230	170	295	0.25	0.080	40	0.70	41.31	133.33
			240	190	306	0.30	0.080	40	0.56	59.87	171.88
			260	212	337	0.32	0.110	55	0.66	62.43	171.88
			280	233	346	0.40	0.120	60	0.54	94.57	150.00
4	Triangle	C.E.	186	110	242	0.22	0.042	21	0.51	35.12	95.45
			200	134	260	0.25	0.058	29	0.58	40.73	116.00
			220	162	284	0.25	0.065	32.5	0.59	44.37	130.00
			240	188	305	0.28	0.082	41	0.61	53.24	146.43
			260	211	325	0.31	0.100	50	0.62	63.22	161.29
			280	233	344	0.40	0.125	62.5	0.56	92.79	150.25
5	Triangle	Maspion	201	128	264	0.25	0.050	25	0.50	43.60	100.00
			220	154	286	0.25	0.070	35	0.64	42.43	140.00
			230	169	298	0.25	0.080	40	0.70	41.31	160.00
			240	180	307	0.25	0.082	41	0.68	43.81	164.00
			260	206	329	0.30	0.100	50	0.64	59.87	166.67
			280	228	348	0.35	0.125	62.5	0.64	75.30	178.57

DEFINITIONS:

V_L	LINE VOLTAGE
V_B	BALLAST VOLTAGE DROP
V_F	FILAMENT VOLTAGE DROP
A	LINE CURRENT
θ	WATTMETER DEFLECTION
W	INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F.	BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
VAR	REACTIVE POWER = V_L x A x Sin ϕ
W/A	WATT PER AMPERE

TABLE 13: CHARACTERISTICS OF 40W PHILIPS EM BALLAST OPERATING ON 40W FLOURESCENT LAMPS AT VARIOUS VOLTAGE LEVELS

S/No	BALLAST/LAMP BALLAST TYPE	COMBINATION LAMP TYPE	V_L	V_B	V_F	A	θ	W	P.F	VAR	W/A
1	Philips	Philips	181	125	242	0.30	0.060	30	0.55	45.26	100.00
			200	147	265	0.31	0.078	39	0.63	48.20	125.81
			220	173	287	0.31	0.090	45	0.66	51.25	145.16
			230	185	297	0.35	0.100	50	0.62	63.09	142.86
			240	197	306	0.40	0.106	53	0.55	80.04	132.50
			260	221	326	0.50	0.130	65	0.50	112.58	130.00
			274	238	339	0.55	0.144	72	0.48	132.89	130.91
2	Philips	SiBalec	166	103	220	0.25	0.044	22	0.53	35.19	88.00
			200	151	259	0.30	0.072	36	0.60	48.00	120.00
			220	175	280	0.31	0.090	45	0.66	51.25	145.16
			230	187	290	0.35	0.098	49	0.61	63.87	140.00
			240	199	298	0.50	0.100	50	0.42	109.09	100.00
			260	223	319	0.62	0.120	60	0.37	149.62	96.77
			274	238	331	0.65	0.140	70	0.39	163.77	107.69
3	Philips	Osram	164	82	217	0.21	0.040	20	0.58	28.04	95.24
			200	145	265	0.30	0.078	39	0.65	45.60	130.00
			220	172	286	0.31	0.090	45	0.66	51.25	145.16
			230	185	294	0.35	0.100	50	0.62	63.09	142.86
			240	198	304	0.40	0.102	51	0.53	81.33	127.50
			260	223	323	0.50	0.122	47	0.44	144.80	122.00
			274	239	335	0.58	0.142	71	0.45	142.18	122.41
4	Philips	C.E.	171	99	228	0.30	0.042	21	0.41	40.80	70.00
			200	144	264	0.30	0.080	40	0.67	44.72	133.33
			220	173	286	0.31	0.098	49	0.72	47.33	158.06
			230	187	293	0.38	0.100	50	0.57	71.69	131.58
			240	200	303	0.40	0.102	51	0.53	81.33	127.50
			260	224	322	0.50	0.122	61	0.47	114.80	122.00
			274	235	330	0.55	0.140	70	0.46	133.46	127.27
5	Philips	Maspion	159	71	209	0.21	0.030	15	0.45	29.83	71.43
			200	142	266	0.29	0.078	39	0.67	42.83	134.48
			220	171	289	0.30	0.090	45	0.88	48.28	150.00
			230	183	298	0.35	0.100	50	0.62	63.09	142.86
			240	196	308	0.40	0.102	51	0.53	81.33	127.50
			260	221	326	0.51	0.126	63	0.48	116.68	123.53
			274	234	335	0.55	0.142	71	0.47	132.93	129.09

DEFINITIONS:

V_L	LINE VOLTAGE
V_B	BALLAST VOLTAGE DROP
V_F	FILAMENT VOLTAGE DROP
A	LINE CURRENT
θ	WATTMETER DEFLECTION
W	INPUT LINE WATTAGE = θ x VOLTAGE FACTOR x CURRENT FACTOR
P.F.	BALLAST/LAMP COMBINATION POWER FACTOR = $W/V_L A$
VAR	REACTIVE POWER = V_L x A x Sin ϕ
W/A	WATT PER AMPERE