Title
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INITIAL TESTING ON LITEK LAMPS

Memorandum by Francis Rubinstein

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NOVEMBER 1981

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LAWRENCE BERKELEY LABORATORY
Bldg.: 90 Room: 3111 Ext.: 4096

MEMORANDUM

DATE: November 20, 1981

TO: Lighting Systems Research Group

FROM: Francis Rubinstein

RE: Initial Testing on Litek Lamps

Introduction

The electrical, photometric and color-rendering characteristics of nine Litek lamps were measured prior to life-testing. This memorandum describes the testing process and the results.

Test Procedure

The testing process was subdivided into three parts as follows:

Electrical + Photometric

- Input power
- Current
- Power factor
- Luminous flux
- Efficacy

Color

- Spectral power distribution
- Correlated color temperature
- General color-rendering index
- Chromaticity coordinates

Supplemental

- Current waveform
- Frequency components
- Flicker
- Voltage regulation

Electrical, photometric and color-rendering characteristics were measured for all nine lamps. For the supplemental tests, only selected lamps were analyzed.

Due to the lack of an amalgam in these prototype lamps, the light output is a function of burning time. Once turned on, these lamps reach peak efficacy in two to five minutes and then drop slowly over a period of hours. Consequently, all electrical and photometric properties were measured during this initial five-minute period and peak results recorded. These measurements were all performed in the integrating sphere using a Clarke-Hess 255 wattmeter and Tektronix J-16 photometer.

Measurement of the spectral power distributions (SPDs) requires about 10 minutes using our equipment. To minimize changes in time, all SPDs were measured after allowing the lamps to stabilize for at least 30 minutes. SPDs were measured using an EG&G Electro-Optics 555 spectroradiometer and the integrating sphere.

Supplemental measurements were made using a UDT PIN 10 DP photometer for the flicker measurements and an HP 3585A spectrum analyzer for the current waveform spectrum analysis.

Test Results

Electrical and photometric test results are tabulated in Table 1 for all nine lamps. Lamp #1 (56.8 lumens/watt) shows the highest efficacy of all lamps tested due to the use of faster switching field-effect transistors in the driver. The average peak light output of the remaining eight lamps is 1665 lumens with an average peak efficacy of 52.5 lumens/watt. Standard deviations for luminous flux and efficacy (±107 lumens and ±2.5 lumens/watt, respectively) are shown to indicate the variability within this small sample of lamps.

Chromaticity characteristics are shown in Table 2. The average correlated color temperature was found to be 4815°K with a spread of ±112°K about the average for the nine lamps measured. The average general color-rendering index is 15.7% with a spread of ±2.9%. Spectral power distribution data were taken for all nine lamps. The SPD for a typical lamp is shown in Fig. 1. The chromaticity coordinates (averaged over the nine lamps) are plotted in Fig. 2 to indicate the color of these lamps relative to other fluorescent sources. The Litek lamps are seen to be significantly displaced from the Planckian locus. The ellipse indicates the spread of chromaticity coordinates relative to the average.

Line voltage and current waveforms for Lamp #3 are shown in Fig. 3. Fig. 4 is the current waveform plotted in the frequency domain -- the fundamental and first nine harmonics are shown. Fig. 5 is a plot of the line current waveform plotted in the frequency domain (0-40 MHz). The 13.56 MHz and 27.12 MHz lines are clearly seen 14 and 28 db, respectively, below the fundamental. Flicker is plotted in Fig. 6. (The lower line is the zero light reference level.) Percent flicker is found to be approximately 10%.

The variation of light output and power input for various input voltages is plotted in Fig. 7. The efficacy is seen to be 12% higher when the lamp is operated at 83% of the rated voltage.

Discussion

The efficacy of these electrodeless Litek lamps is quite high (52.5 lumens/watt) relative to other compact fluorescent designs (typically 45 lumens/watt). The reasons for this increased efficacy are twofold:

- Increased efficacy due to elimination of the electrodes
- Increased efficacy due to the large yellow-green component

The high green component is also responsible for the low color-rendering properties of these lamps and should therefore be considered a design compromise. Relative to other commercially available light sources, the color-rendering properties of these lamps are quite low -- 15.7% compared to 21% for high-pressure sodium and 15% for clear mercury (the CRI for low-pressure sodium is -44%). The manufacturer can improve the color rendition of these lamps by increasing the relative strength of the 610 nm narrow-band phosphor line.

The lack of an amalgam in these lamps results in a gradual drop in both light output and efficacy as the lamps heat up. Approximately two hours after turn-on, the light output and efficacy reach steady-state values about 15% lower than the initial peak values. These gradual changes, presumably a result of increased mercury vapor pressure, also affect the chromaticity coordinates. From Table 2 it is seen that, as the lamps heat up, there is a shift toward the blue-green, resulting in higher color temperatures and lower CRIs. The effect of burning time on the chromaticity coordinates is shown in Fig. 8 (note 8a, 8b, and 8c).

Harmonic component of the input current waveform is shown in Fig. 4. The 3rd harmonic is about 1.5 db lower than the fundamental. The 5th is 5 db below the fundamental. These harmonics are due to the nonsinesoidal waveshape and also result in the relatively low power factor. Fig. 5 shows the presence of the lamp's fundamental drive frequency (13.56 MHz) and the 2nd harmonic.

The amount of flicker associated with these lamps is fairly low (10%) compared to conventionally ballasted fluorescent lamps which have about 25% flicker.

Conclusion

To obtain widespread use in the residential sector, an energy-efficient replacement for the incandescent lamp should have the following properties (see, for example, Bouwknegt, "Compact Fluorescent Lamps"):

- High efficacy (preferably three times as efficient as the product it replaces)
- Good color rendition (at least 50%)
- Small size and light weight
- Ability to burn in any position
- Instant start capability

In addition, the product should be "cost-effective" in a life-cycle cost analysis.

The Litek lamp prototypes submitted to LBL meet all these specifications except for color rendition. As previously discussed, the color-rendering properties of these lamps can be easily improved by adjusting the mix of the three component phosphors.

It should be recognized that these lamps are prototypes and that product performance could be enhanced by various methods. In particular, efficacies over 60 lumens per watt may be possible by optimizing the lamp shape. Improvements in the efficiency of the driver may also be possible.

If the electrodeless fluorescent lamp can be sold to the end user at $10 to $15, it can be considered a viable and economical replacement for the incandescent lamp in the 1980's.

Attachments

FR:pb

Table 1

LITEK LAMPS
(Electrical and Photometric Characteristics)

Lamp #	Elapsed Time (Min)	Lumens	Power (Watts)	Current (ma)	P.F. (%)	Efficacy (l/w)
1†	2	1651	29.1	420	58.0	56.7
	3*	1659	29.2	425	57.5	56.8
	5	1656	29.3	427	57.5	56.5
2	2*	1710	32	459	58.4	53.4
	3	1707	31.9	459	58.2	53.5
	5	1630	31.3	452	58.0	52.1
3	2	1520	30.7	445	57.8	49.5
	3*	1545	30.8	442	58.4	50.2
	5	1534	30.8	445	58.0	49.8
5	2*	1893	34	481	59.2	55.7
	3	1871	33.8	463	61.1	55.4
	5	1813	33.5	463	60.6	54.1
6	2	1517	31.1	445	58.5	48.8
	3*	1554	31.3	448	58.5	49.6
	5	1521	31.2	448	58.3	48.8
7	2*	1633	31.9	451	59.2	51.2
	3	1577	31.4	447	58.8	50.2
	5	1561	31.5	448	58.9	49.6
8	2*	1744	32.2	466	57.9	54.2
	3	1724	32	462	58.0	53.9
	5	1695	31.8	460	57.9	53.3
9	2	1612	29.6	419	59.2	54.5
	3*	1633	29.3	415	59.1	55.7
	5	1587	28.6	409	58.6	55.5
10	2*	1615	32.1	460	58.4	50.3
	3	1538	31.7	459	57.8	48.5
	5	1468	31.5	459	57.5	46.6
Average Peak Values**		1665	31.7	453	58.6	52.5
Standard Deviation		107	1.34	19.4	0.47	2.5

NOTE: Input voltage for all tests: 119.4 VAC

† Higher-efficacy lamp driver
* Peak values
**All lamps except lamp #1

Table 2

LITEK LAMPS
(Chromaticity Characteristics)

Lamp #	Trial #	Elapsed Time Before Measurement (min)	Chromaticity Coordinates X	Chromaticity Coordinates Y	Correlated Color Temp. (°K)	General Color Rendering Index (%)
1		35	.3642	.4167	4665	13.9
2		40	.3539	.4054	4893	18.2
3	a	50	.3596	.4096	4758	18.9
	b	195	.3580	.4088	4797	18
5	a	45	.3540	.4093	4903	12.6
	b	60	.3513	.4077	4969	11.6
6		100	.3540	.4102	4905	11.4
7	a	45	.3567	.4105	4836	14.2
	b	60	.3532	.4080	4919	13.5
8	a	30	.3595	.4113	4766	16.2
	b	45	.3565	.4090	4837	15.8
	c	65	.3559	.4085	4852	15.6
9		95	.3658	.4145	4612	18.9
10		95	.3555	.4066	4855	18.2
Average			.3575	.4100	4815.5	15.7
Standard Deviation			.0047	.0036	111.5	2.9

SPECTRAL IRRADIANCE MEASUREMENT

LAMP TYPE:Litek #8   Comment:45 minutes burning - Trial 2
OP:F.Rubinstein   DATE:10/30/81

10nm MEAS. INC.
Sum from 350 to 800nm= 1.917E-05 Watts/cm^2
Lumens per square foot(Footcandles)= 6.081E 00
x=0.3565 y=0.4090 u=0.1982 v=0.3411 C.C.T.(Kelvin)= 4837 mired= 206.7
General color rendering index (Ra)= 15.8
R(9)=$$$$$ R(10)= 36.8 R(11)= -7.9 R(12)= -5.7 R(13)= 15.9 R(14)= 72.4

Figure 1

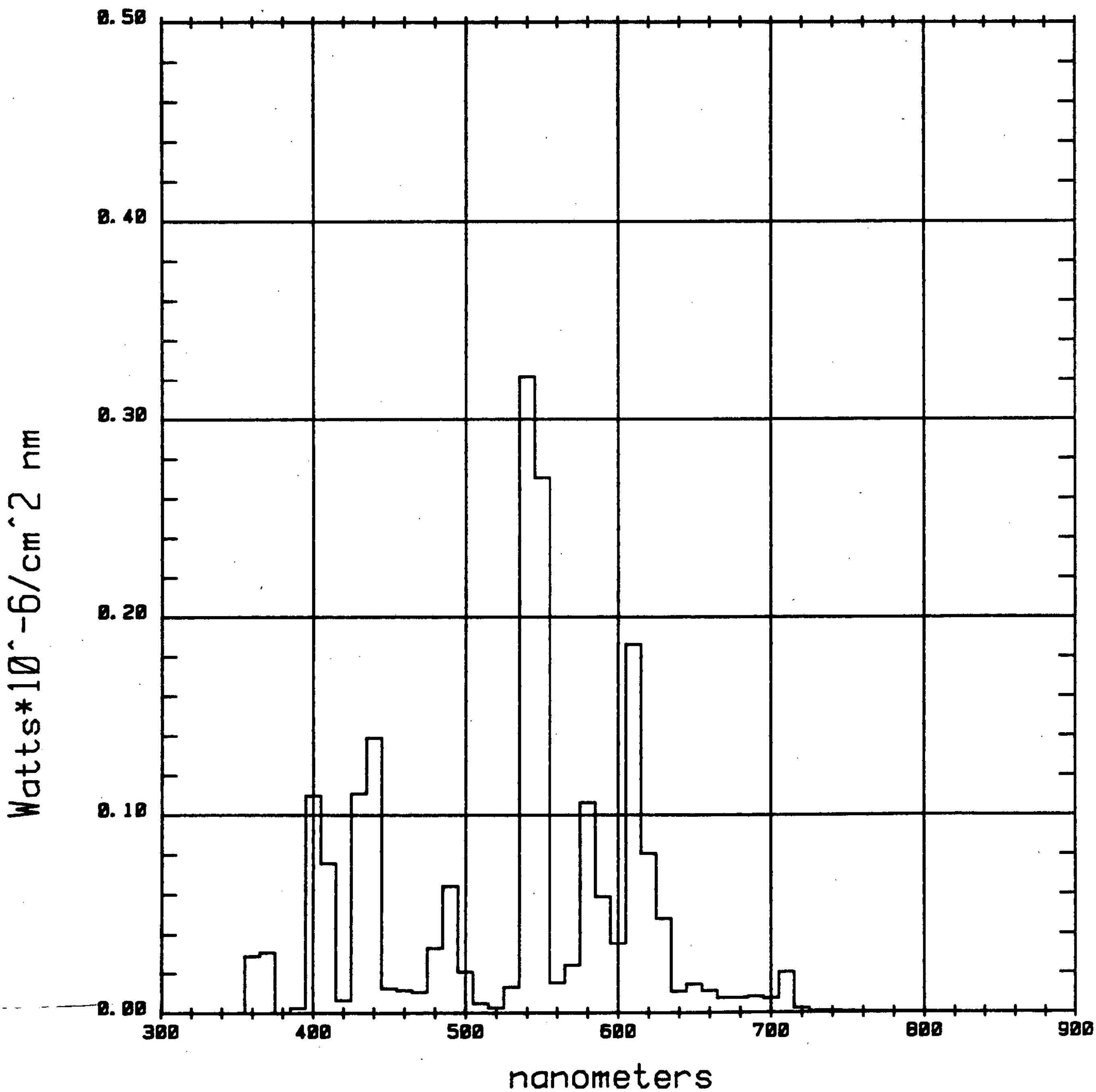


Figure 2

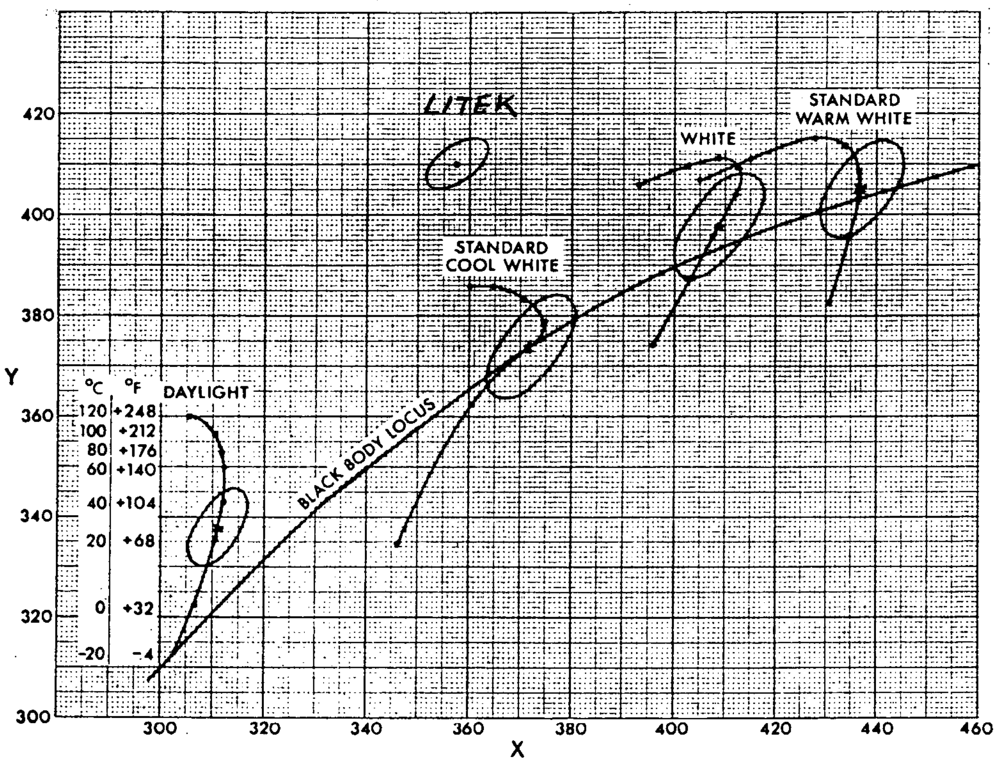


Fig. 8-36. Typical color shift characteristic of a fluorescent lamp with changes in ambient temperature. The MacAdam 4-step ovals illustrate the tolerance limits for the particular white. Color shift over a normal temperature range is in the same order of magnitude as that which may be experienced between lamps of the same nominal color due to manufacturing variations, depreciation through life, etc. (The lowest point on each curve is at −20°C (−4°F), the top point at 120°C (248°F), intermediate points are 20°C (36°F) apart; see daylight lamp.)

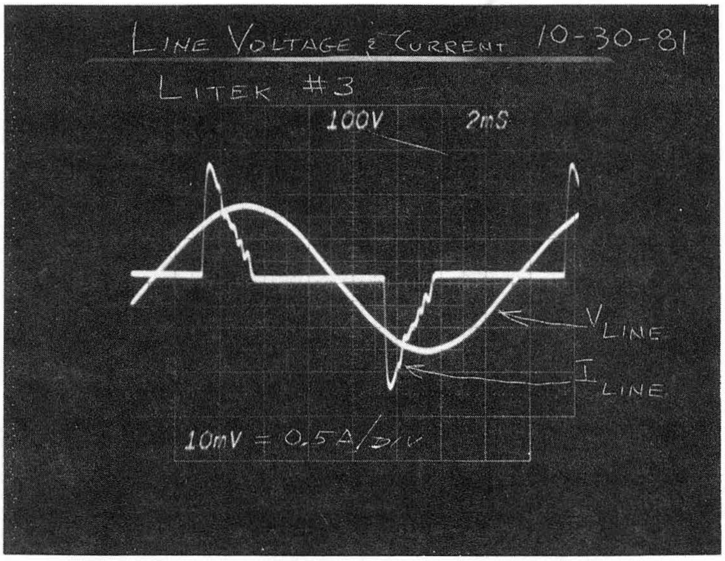


Figure 3

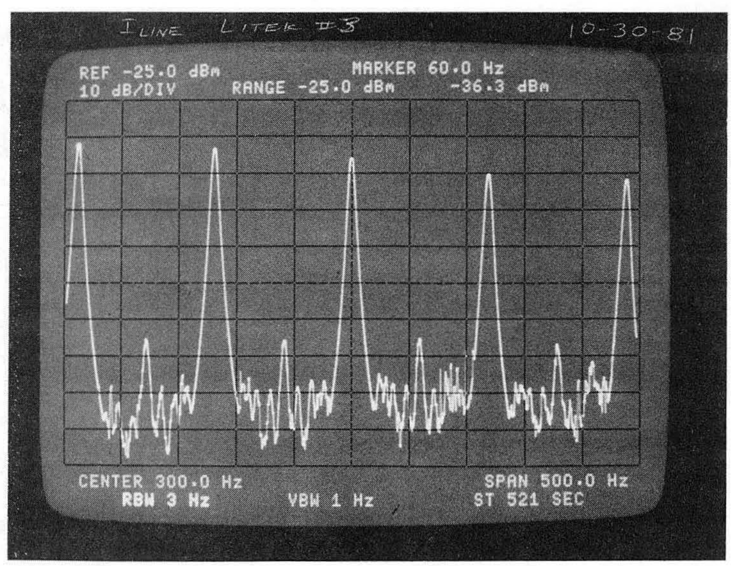


Figure 4

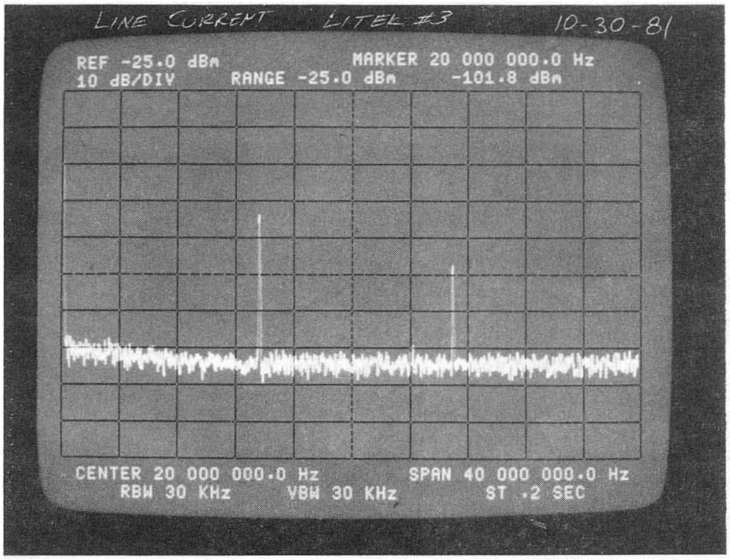


Figure 5

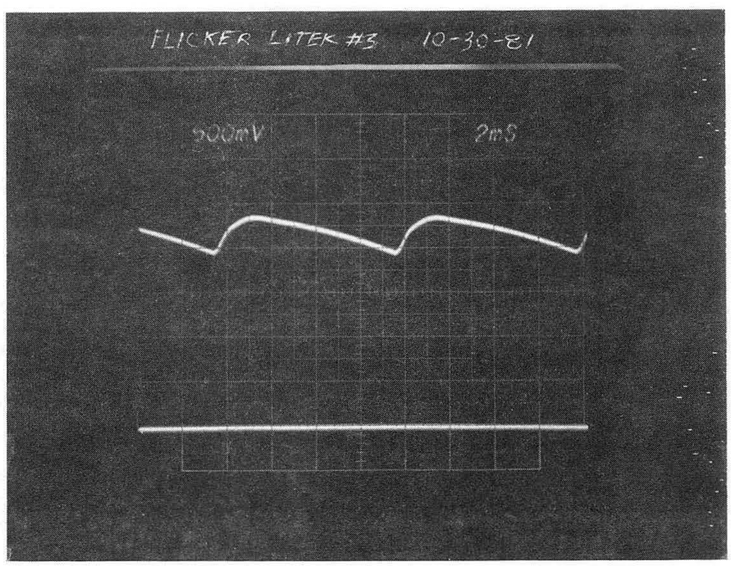


Figure 6

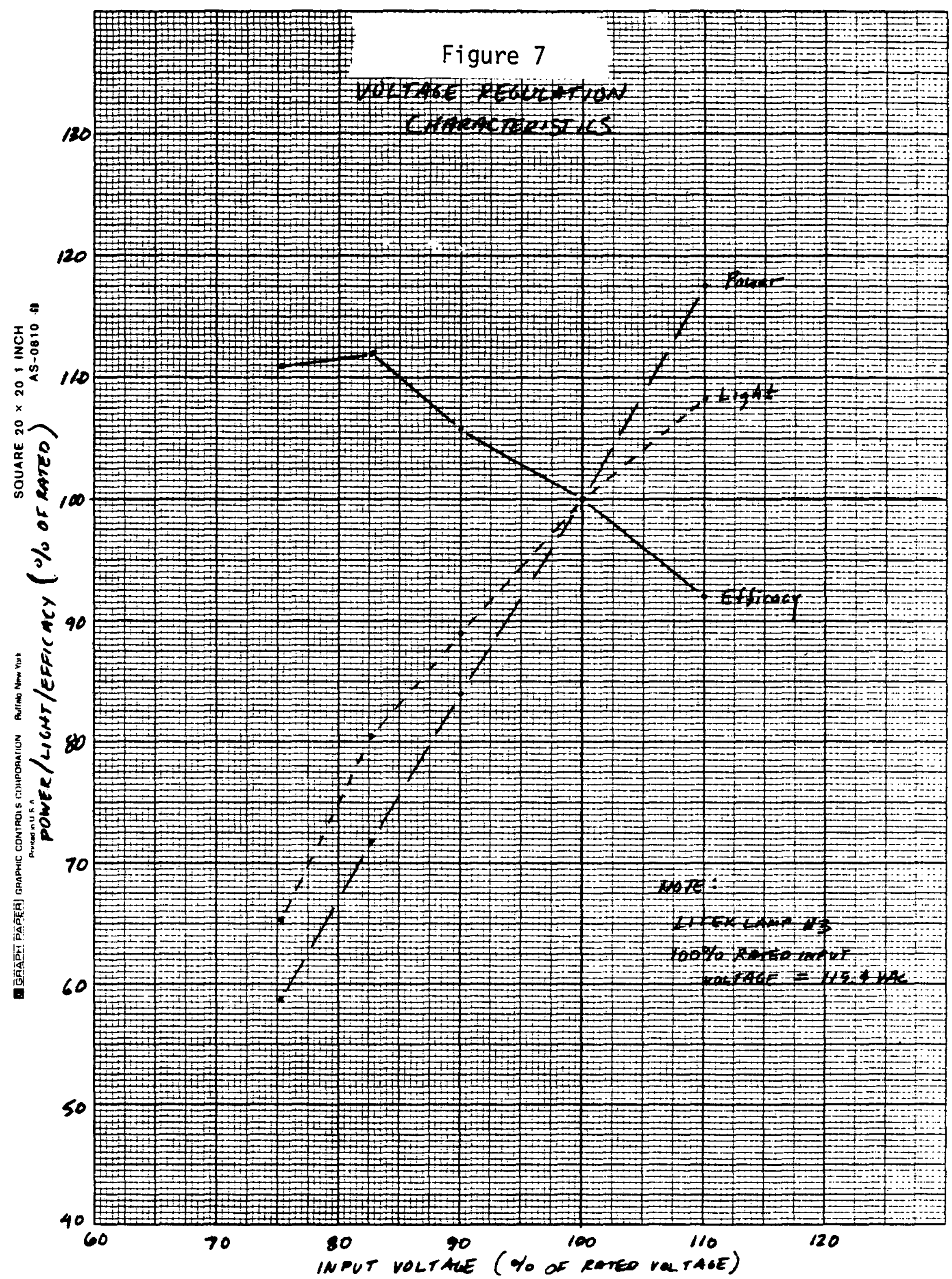
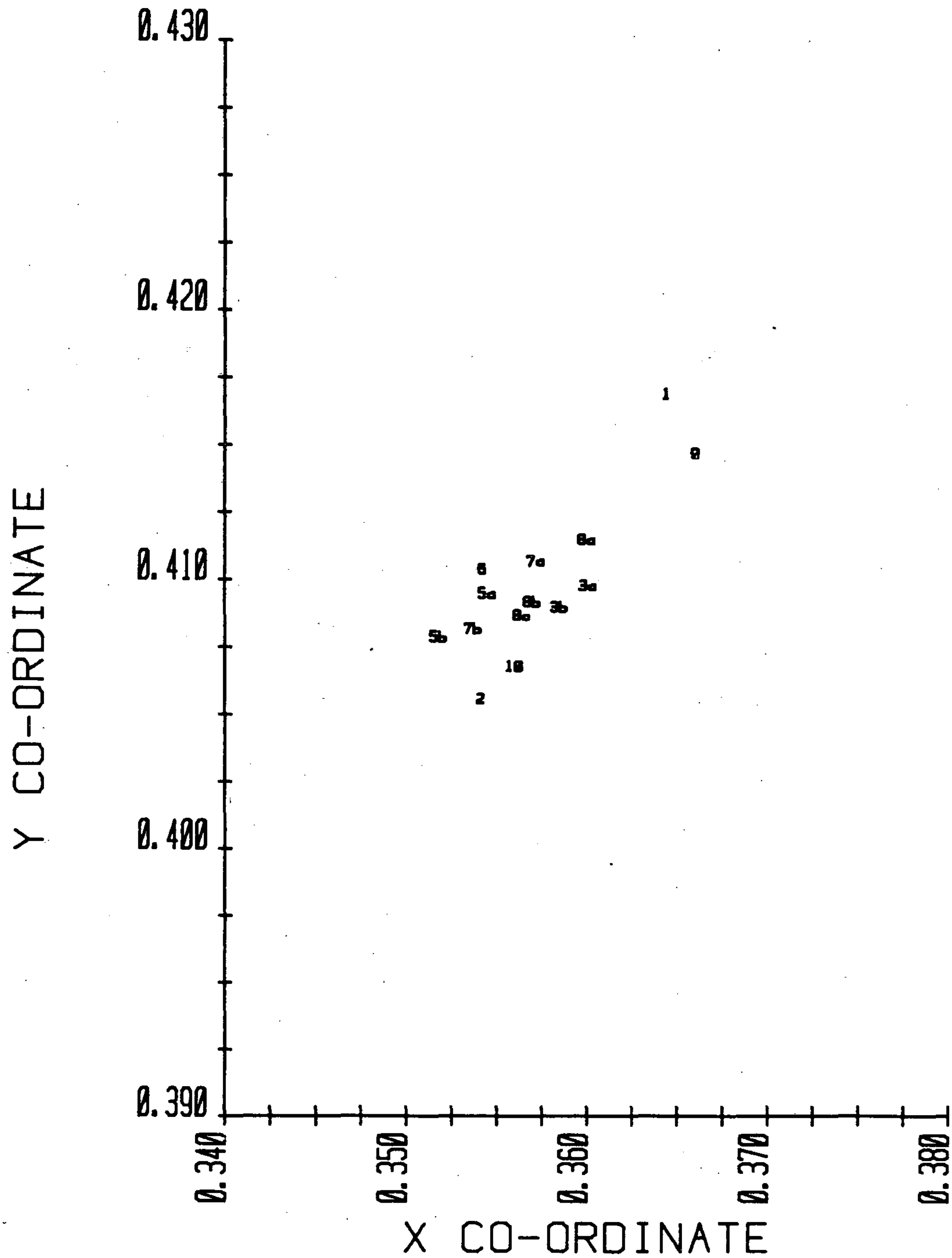

VOLTAGE REGULATION
CHARACTERISTICS
POWER/LIGHT/EFFICACY (% OF RATED)
INPUT VOLTAGE (% OF RATED VOLTAGE)
Power
Light
Efficacy
NOTE:
LITEK LAMP #3
100% RATED INPUT
VOLTAGE = 115.4 VAC
40
50
60
70
80
90
100
110
120
130
60
70
80
90
100
110
120
GRAPH PAPER GRAPHIC CONTROLS CORPORATION Buffalo New York
Printed in U.S.A.
SQUARE 20 × 20 1 INCH
AS-0810

Figure 7

Figure 8



0.430
0.420
0.410
0.400
0.390
Y CO-ORDINATE
1
9
8a
7a
6
3a
5a
8b
3b
8a
7b
5b
10
2
0.340
0.350
0.360
0.370
0.380
X CO-ORDINATE

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