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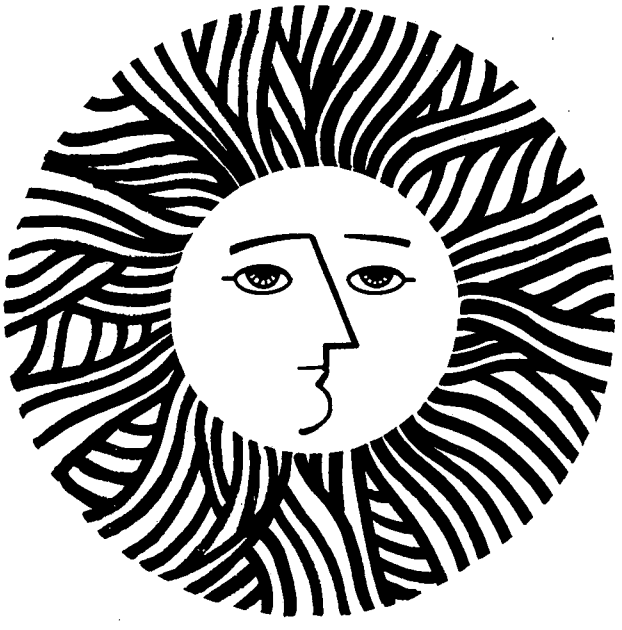

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MEMORANDUM

DATE: September 1, 1982

TO: Lighting Systems Research Group

FROM: Greg Ward and Francis Rubinstein

RE: Electrical and Photometric Tests on General Electric Halarc Lamps

Introduction

This memorandum describes the electrical, photometric and chromatic performance of the General Electric Halarc lamps after 3000 hours of burning time. Performance at 350 hours was described in a previous memo dated January 18, 1982. Initial performance was described in a memo dated August 12, 1981. Lamp performance has also been measured at 750 and 1500 hours; these data will be used in this memorandum to evaluate the performance of the Halarc lamps over time.

Test Procedure

Before taking any measurements, each lamp was placed in the integrating sphere base down and burned for 20 minutes in order to reach thermal equilibrium. The sphere was then closed, and electrical and photometric data were taken.

The equipment used for all measurements is listed below.

Equipment	Parameter Measured
Clarke-Hess 255 wattmeter	Power, input voltage, current
Tektronix J-16 photometer	Luminous flux
EG&G Electro-Optics 555 spectroradiometer	Spectral power distribution

Luminous flux values were calculated using an NBS-calibrated incandescent lamp as the transfer standard.

Test Results

Major test results of the lamp performance after 3000 hours are given in the lower half of Table 1. Initial lamp performance is given in the upper half of Table 1, and the percent change in the average of each parameter after 3000 hours is given at the bottom. Results of other measurements are given graphically in Graphs 1-11.

Graphs 1-3 represent average values of the y-parameters (Flux, Power and Efficacy, respectively), and the bars on the Graphs represent the standard deviation at each point. The standard deviation relates to the statistical distribution about the mean of our sample. It is not related therefore to the experimental uncertainty. The experimental uncertainty for each parameter is given below.

Parameter	Estimated Instrumental Uncertainty
Input voltage	±0.8 volts
Current	±20 milliamps
Power	±1 watt
Relative luminous flux	±45 lumens
Absolute luminous flux	±100 lumens
Color temperature	±50 degrees Kelvin
Color-rendering index	±1.0%

In Graphs 4 and 6, Flux and Efficacy are detailed for lamps which were tested at every data point. In Graphs 5 and 7, the lamps which were not tested at every data point are plotted. Lamp 1 was used for demonstration purposes; lamps 2, 9, 10, 12 and 16 burned out before 3000 hours and lamp 17 was started out of synchrony with the other lamps (16 and 17 are replacements for lamps 3 and 7 which failed to operate initially). None of these lamps were included in the average for Graphs 1-3. Graphs 12 shows the burn-out times for the above mentioned failures.

The average light output of these lamps has dropped 32% after 3000 hours. However, this figure is referenced to 14 hours, rather than 100 hours which is standard for metal halide life testing. By interpolation, a value of 2600 lumens is arrived at for the lumen output at 100 hours. This is 13% higher than G.E.'s rating of 2300 lumens. The drop from this latter figure is 28%. The lumen maintenance curve is plotted

in Graph 1. After 3000 hours, the light output is dropping steadily at about 8% per 1000 hours.

The power consumption during this time has remained fairly constant, so the efficacy has followed the light output closely. After 3000 hours, the average efficacy has dropped 28% from 48.5 to 34.7 lumens/watt. Again, if the efficacy is referenced instead to 100 hours, the drop is slightly less, 25%. Efficacy vs. Time is plotted in Graph 3.

Although the mean values of the other parameters have not changed significantly over 3000 hours, the variability among lamps of the Color Temperature and the Color-Rendering Index have both increased. This can be seen in the bars of Graphs 8 and 9. Initially, the percent deviation of the Color Temperature was 5%. After 3000 hours it is 12%. Likewise, the deviation of the Color-Rendering Index has increased from 4% to 18%. The average Color-Rendering Index has also dropped somewhat, but the Color-Rendering Indexes of some lamps has actually increased, as can be seen in Graph 11. Comparison between the spectral power distributions of the lamps at different times does not reveal a consistent change in specific spectral lines. For some specific lamps, though, some changes in SPD with time are discernable. Graphs 15 and 16 (lamp #15 at 750 and 3000 hrs, respectively) show that the spectral lines at 550, 570 and 600 nm have all decreased with burning time while the line at 540 nm has increased. Graphs 13 and 14 (lamp #11 at 1500 and 3000 hrs, respectively) reveal quite a different change; primarily a decrease in the relative intensity of the 590 nm line with time and an increase in the intensity of the 600 nm line. We are not certain of the significance of these changes. However, it is clear from the integration of spectral irradiance data over two color groupings, blue (380-500 nm) and orange (540-780 nm), that the color of each lamp is changing. Lamp 11, whose Color Temperature has dropped from 2984°K at 1500 hours to 2496°K at 3000 hours, has an orange:blue ratio which has increased from 3.44 to 4.83. This indicates that the color of the lamp is becoming more red with age. By contrast, the Color Temperature of lamp 15 has increased from 3007°K at 750 hours at 3322°K at 3000 hours and has a corresponding drop in the orange:blue ratio from 3.26 to 2.66. The color of this lamp is therefore becoming more blue with age.

Discussion

The rate of lumen depreciation for these lamps is roughly twice that of a standard 400 watt metal halide lamp, which is 4% per 1000 hours after 3000 hours. Also, after 3000 hours, the 400 watt metal halide loses only 13% of its initial output, rather than the 28% that the GE Halarc

has lost. The significance of this comparison is unclear, however, due to the differences between metal halide lamps of different wattages. Comparing specifications for different wattage metal halide lamps, it is apparent that a decrease in lamp power is related to a shorter rated life. While a 400 watt lamp has a rated life of 15000 to 20000 hours, a 175 watt design has a rated lifetime of only 8000 to 10000 hours. Also noteworthy is the fact that the mean lumens* for these two lamps is roughly in the same proportion to their respective initial lumens. This would indicate that the 175 watt lamp not only burns out sooner, but also depreciates faster than the 400 watt. It is therefore somewhat unfair to compare the 55 watt Halarc to a 400 watt metal halide lamp. However, since most available lumen maintenance data is for higher wattage metal halide lamps, it is the only comparison possible.

Looking at the total depreciation over the rated lifetimes of the G.E. Halarc versus the 400 watt metal halide, the numbers are more comparable. The total depreciation for the 400 watt halide is approximately 35%, while the estimated final output at 5000 hours on the Halarcs will be down 39% from the 100 hour initial point. If G.E.'s value of 2300 lumens for the initial output is substituted, this figure drops to 32%. (Calculations assume that the Halarcs continue to depreciate at the 3000 hour rate of 8% per 1000 hours.) Even 39% would not be excessive, in light of the fact that the Halarcs are being life tested at 3 hours per start, rather than 10 hours per start which is standard for metal halide life testing. According to GTE Sylvania data, a higher wattage metal halide lamp will, at 5000 hours burning, depreciate to 78% and 70% of initial lumens for starting cycles of 10 hrs and 5 hrs per start, respectively. Since the rate of lumen depreciation increases with shorter starting cycles, our measured values for a 3 hour starting cycle seem consistent with available data.

Changes in chromaticity with time is a well-documented characteristic of conventional metal halide lamps. These changes, which are presumably due to selective depletion of the various metal additives, also seem to be occurring with the Halarc lamps. The chromaticities of the various lamps tested are not all changing in a uniform manner although the curves in Graph 10 indicate that most lamps are tending towards lower color temperatures and are therefore becoming more red with time. Graphs 17 and 18 (x and y chromaticity co-ordinates, respectively, as a function of time) indicate that while the x coordinate is, on the average, reasonably constant with burning hours, the y coordinate shows a

*Mean lumens is the lumen output of a lamp after burning for 40% of rated life.

slow but consistent decrease with burning time. This translates to an overall shift towards pink as the lamps age.

60% of the lamps tested have survived to 3000 hours (Graph 12). Since 50% of the lamps should still survive by the rated life (5000), our sample of lamps are failing slightly faster than expected. However, this is probably not significant due to our small sample size.

Acknowledgement

This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Building Equipment Division of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

TABLE 1

GE Halarc Lamps

Date: 8/12/81

(After 14 Hours of Burning)

Operating Voltage: 120
Calibration Factor: 1.1352

Lamp No	Cur'nt (mA)	Power (w)	Power Factor (%)	Lux (lux)	Total Flux (lm)	Eff'cy (lm/w)	Color Temp (degK)	CRI (%)
1	780	55.0	58.8	2317	2630	47.8	3038	64.0
2	774	56.0	60.3	2146	2436	43.5	3046	64.4
4	768	54.0	58.6	2269	2576	47.7	2931	62.7
5	812	58.0	59.5	2574	2922	50.4	2892	66.0
6	840	60.0	59.5	2505	2844	47.4	3068	66.4
8	780	55.0	58.8	2307	2619	47.6	3465	60.8
9	819	58.0	59.0	2671	3032	52.3	2912	66.9
10	825	59.0	59.6	2596	2947	49.9	2930	69.0
11	775	55.0	59.1	2360	2679	48.7	2952	64.3
12	802	58.0	60.3	2553	2898	50.0	2974	68.0
13	746	53.0	59.2	2285	2594	48.9	3112	64.3
14	785	56.0	59.4	2317	2630	47.0	2996	63.4
15	799	56.0	58.4	2441	2771	49.5	2961	63.7
AVG:	793	56.4	59.3	2411	2737	48.5	3021	64.9
DEV:	26	2.1	0.6	157	178	2.1	149	2.3

GE Halarc Lamps

Date: 8/19/82

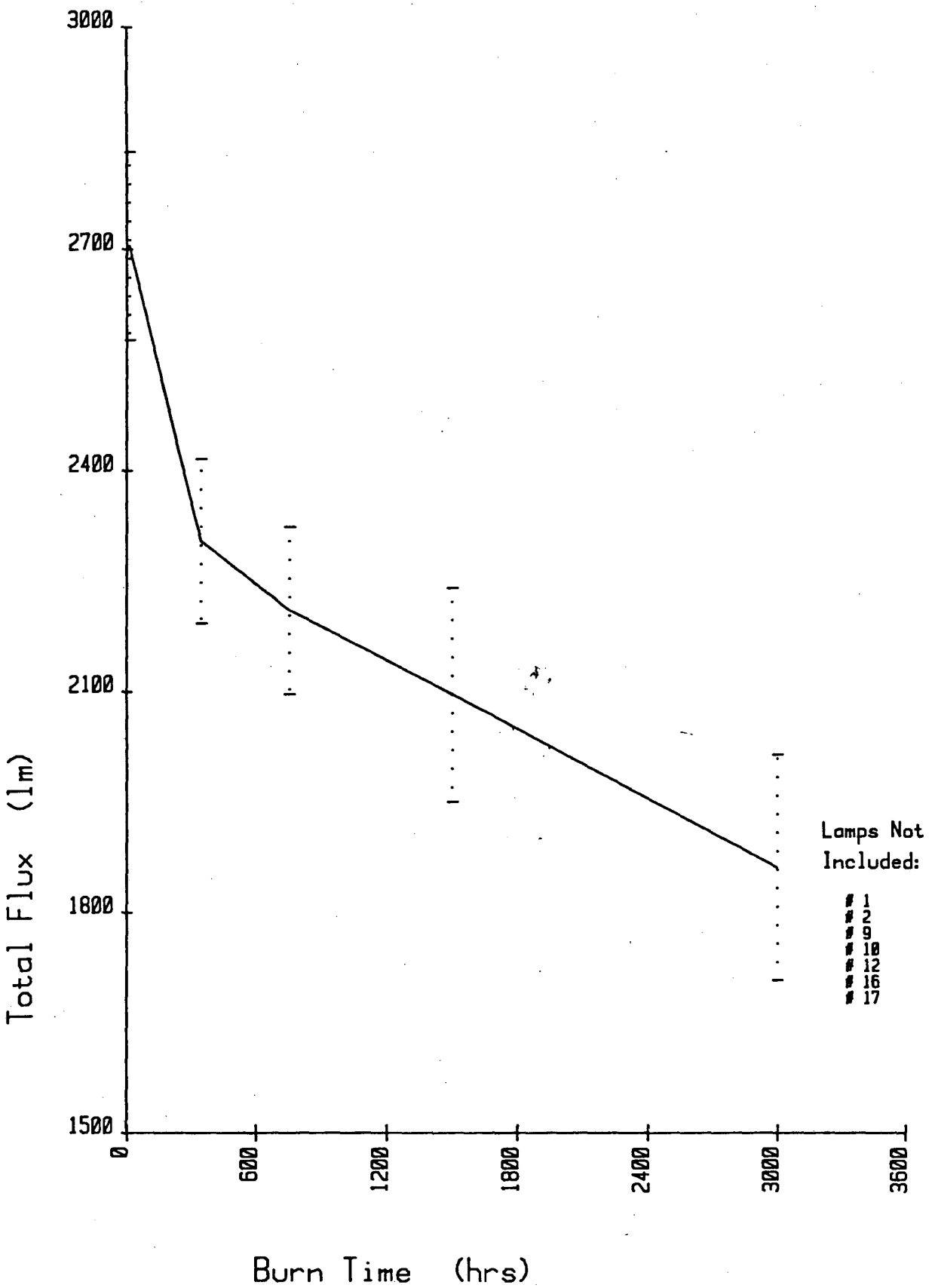
(After 3000 Hours of Burning)

Operating Voltage: 120
Calibration Factor: 1.1352

Lamp No	Cur'nt (mA)	Power (w)	Power Factor (%)	Lux (lux)	Total Flux (lm)	Eff'cy (lm/w)	Color Temp (degK)	CRI (%)
4	720	52.0	60.2	1530	1737	33.4	3080	54.5
5	760	55.5	60.9	1796	2039	36.7	2675	38.2
6	779	57.0	61.0	1775	2015	35.4	2691	54.8
8	732	52.7	60.0	1406	1596	30.3	3360	49.5
11	734	52.5	59.6	1615	1833	34.9	2496	53.3
13	728	52.4	60.0	1645	1867	35.6	2876	54.4
14	740	52.7	59.3	1585	1799	34.1	3364	71.7
15	760	53.9	59.1	1764	2002	37.2	3322	63.0
AVG:	744	53.6	60.0	1640	1861	34.7	2983	54.9
DEV:	20	1.8	0.7	135	154	2.2	346	9.7
CHANGE:	**-6%**	**-5%**	**+1%**	**-32%**	**-32%**	**-28%**	**-1%**	**-15%**

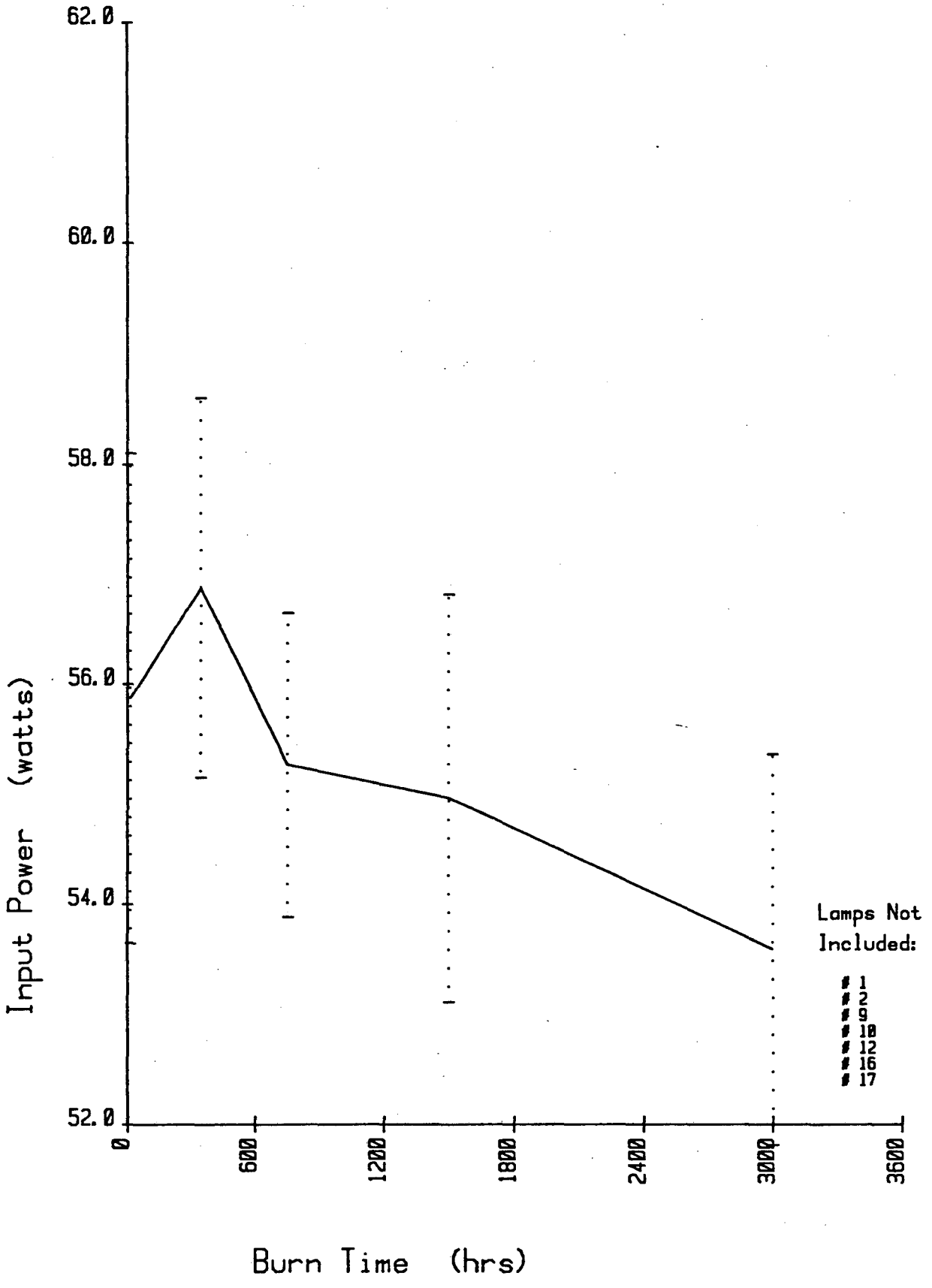
GRAPH 1

GE HALARC LIFE TEST DATA
TOTAL FLUX vs BURN TIME



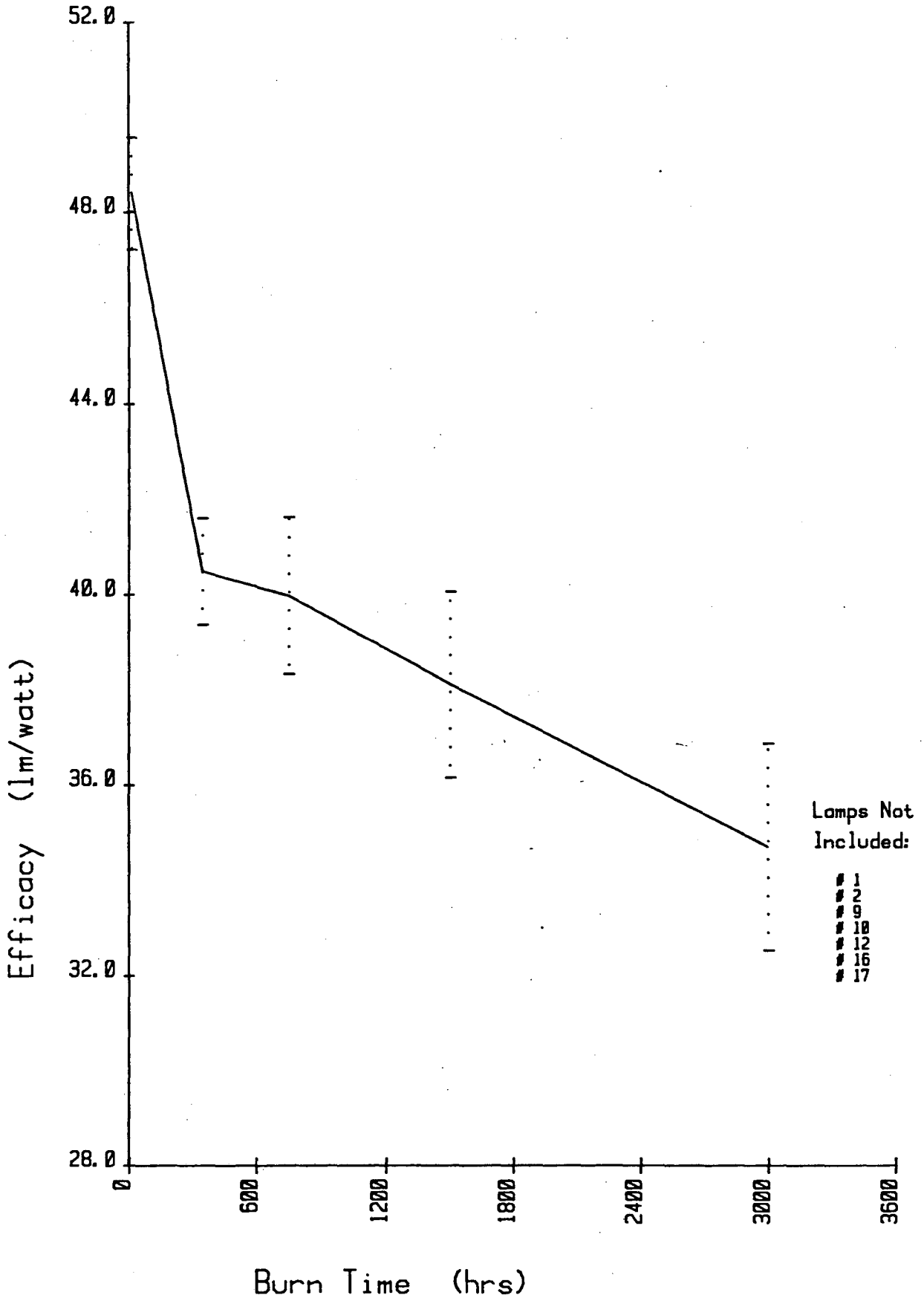
GRAPH 2

GE HALARC LIFE TEST DATA
INPUT POWER vs BURN TIME

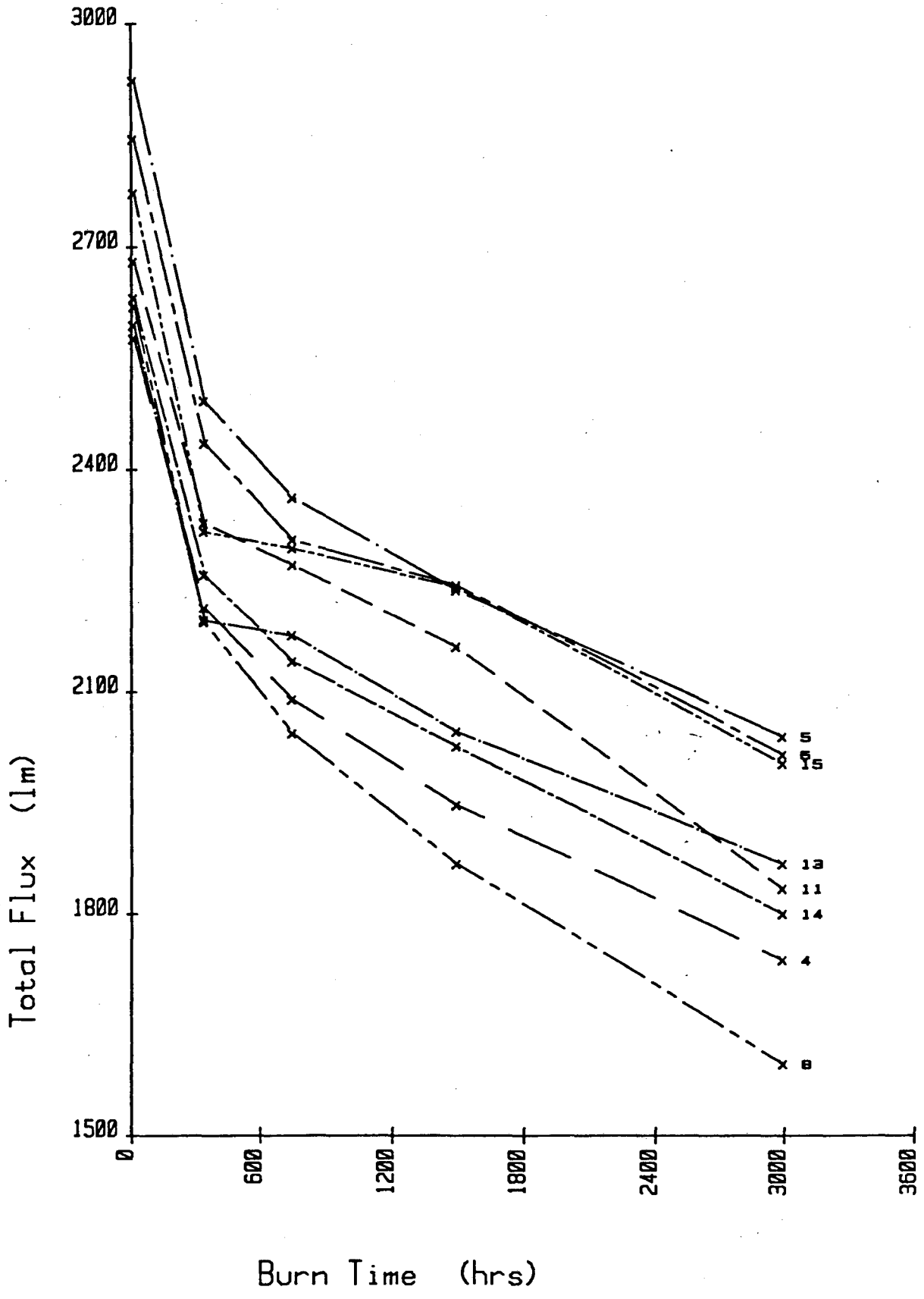


GRAPH 3

GE HALARC LIFE TEST DATA
EFFICACY vs BURN TIME

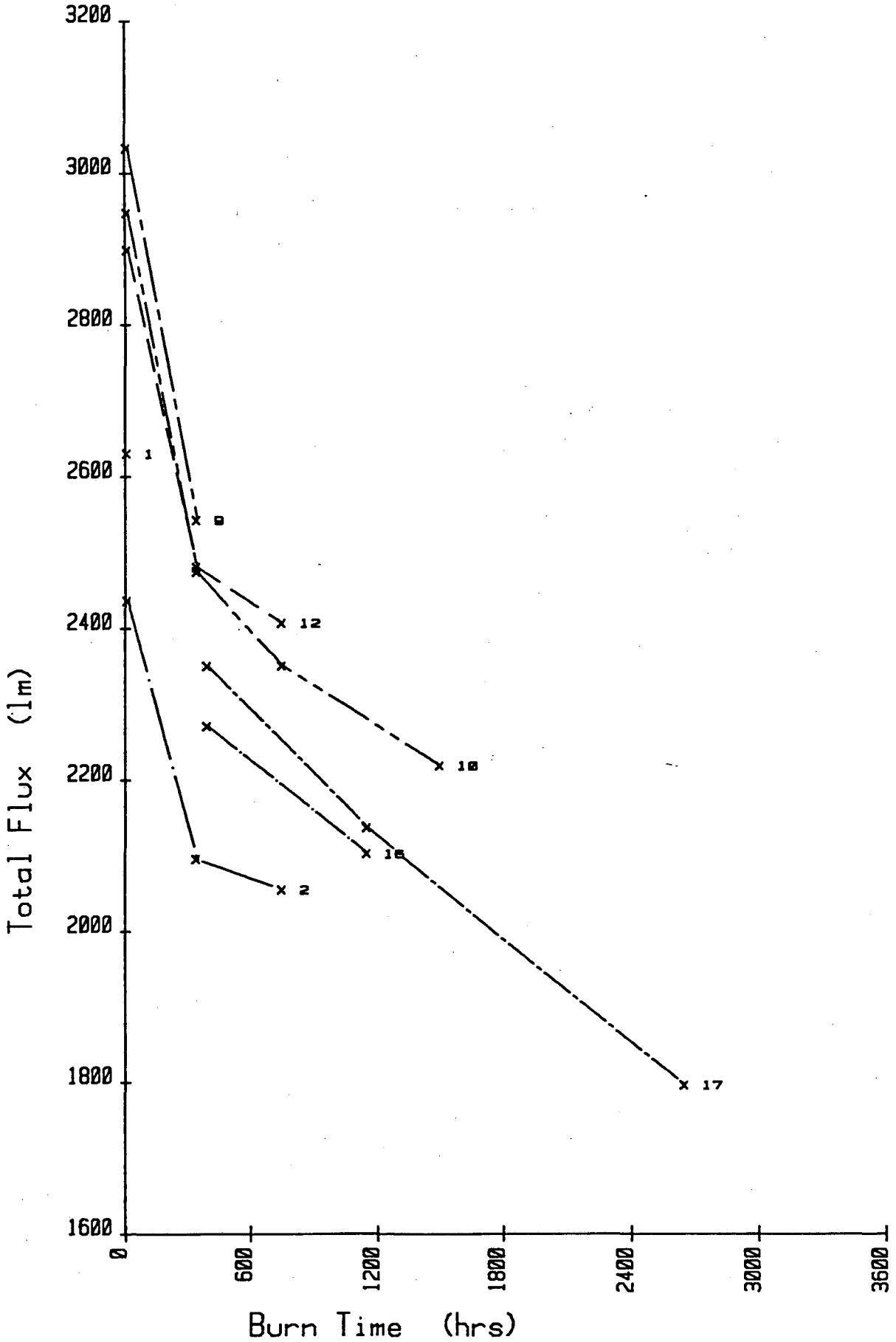


GE HALARC LIFE TEST DATA
TOTAL FLUX vs BURN TIME



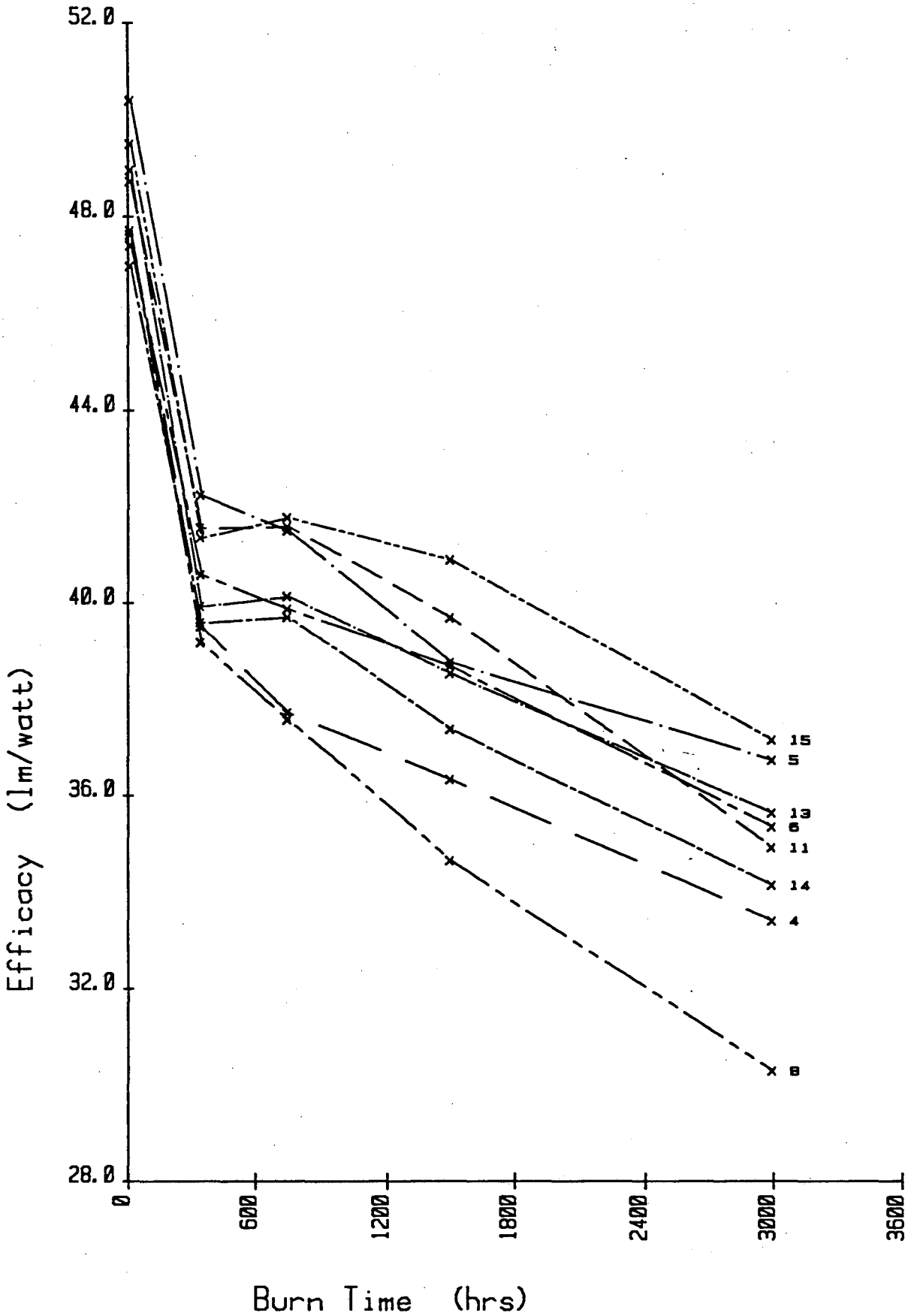
GE HALARC LIFE TEST DATA
TOTAL FLUX vs BURN TIME

GRAPH 5



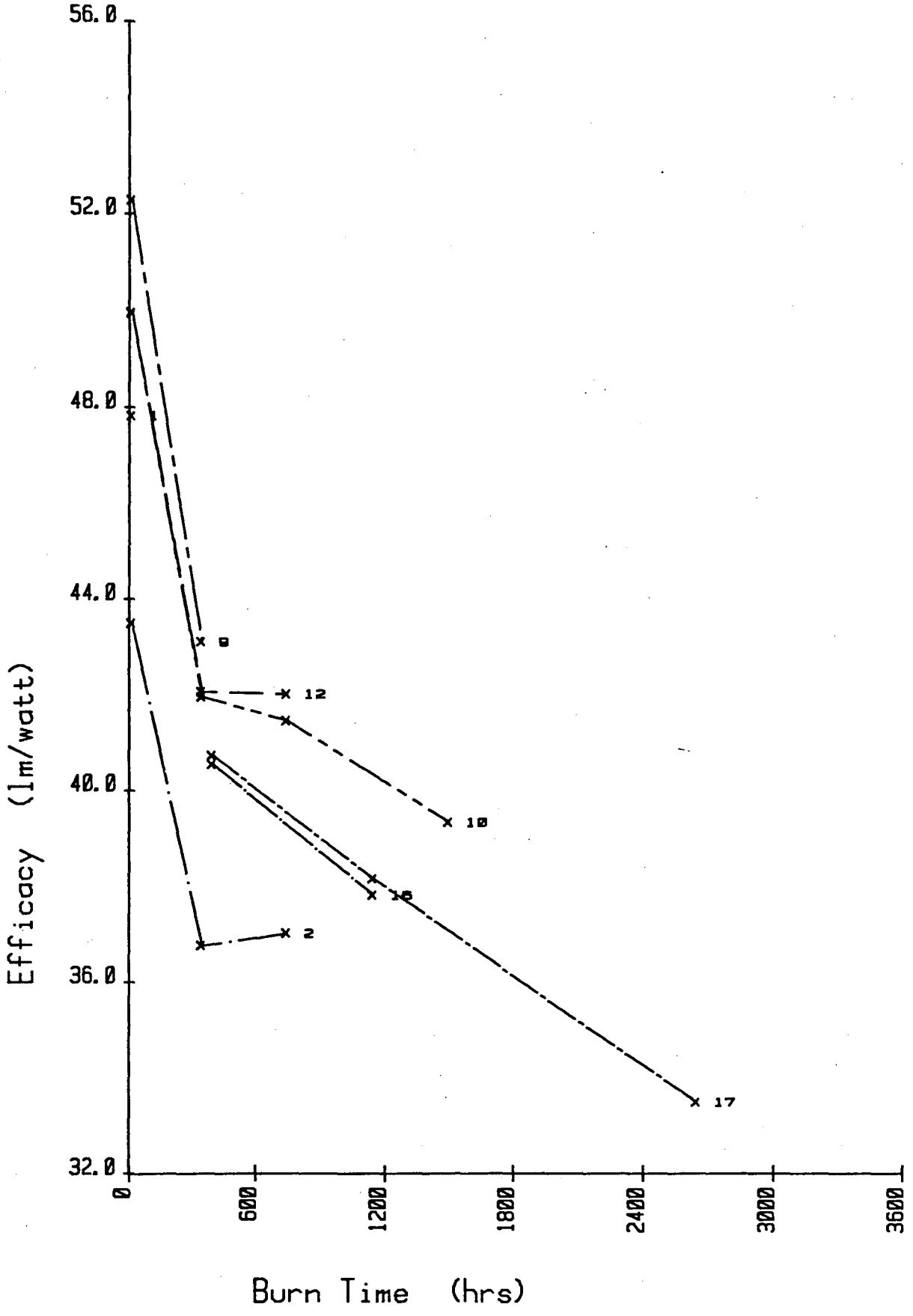
GRAPH 6

GE HALARC LIFE TEST DATA
EFFICACY vs BURN TIME



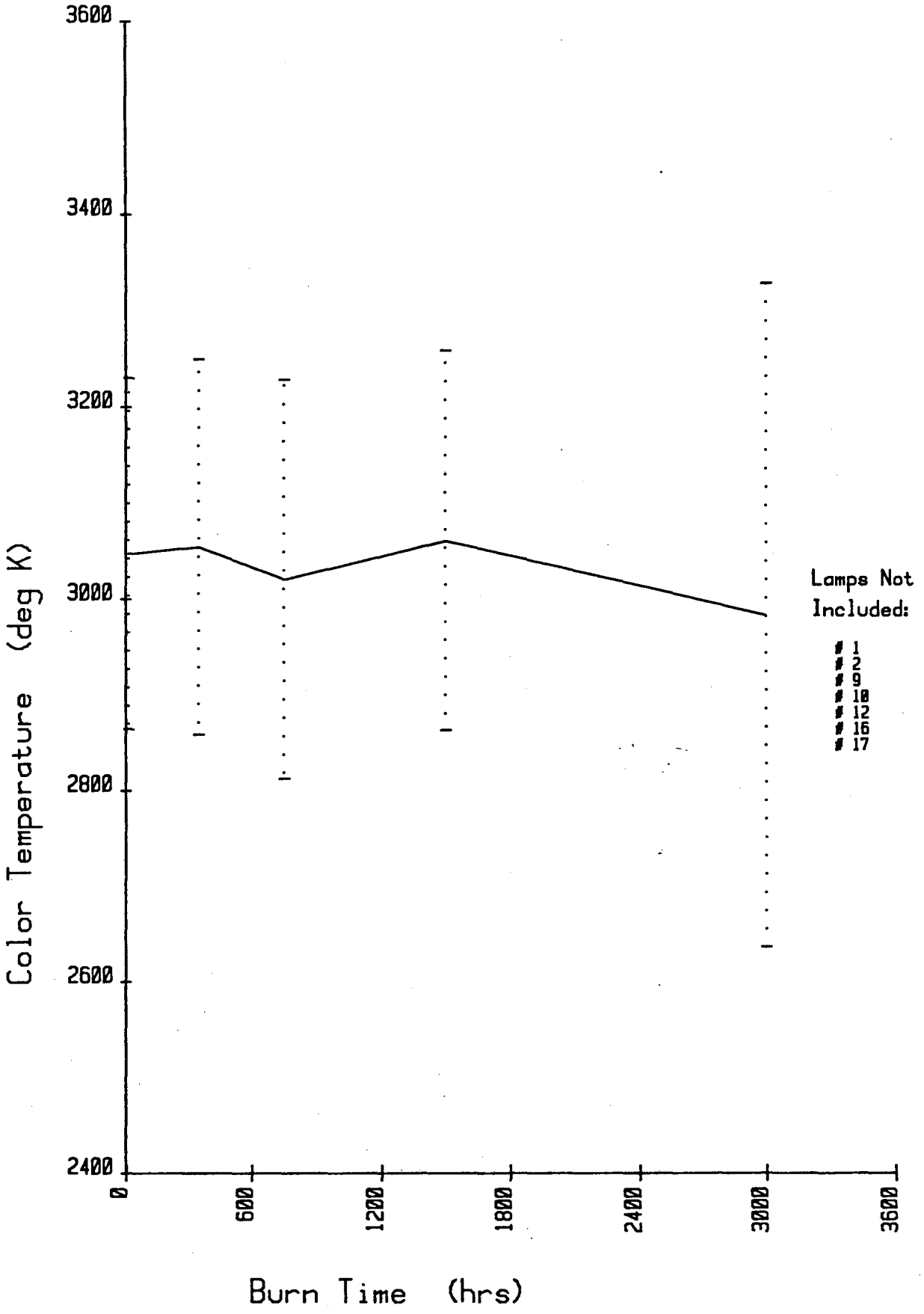
GRAPH 7

GE HALARC LIFE TEST DATA
EFFICACY vs BURN TIME



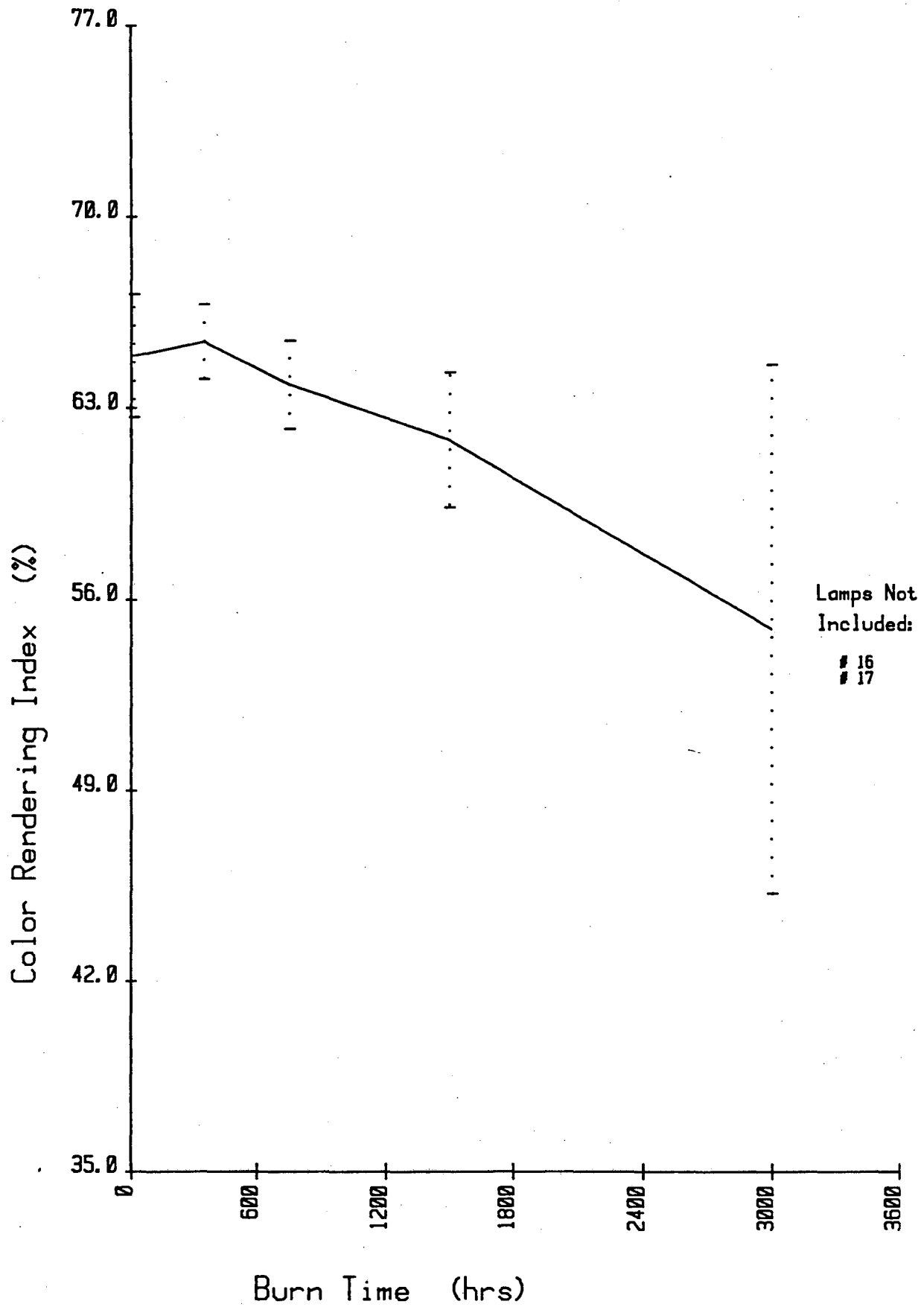
GRAPH 8

GE HALARC LIFE TEST DATA
COLOR TEMPERATURE vs BURN TIME



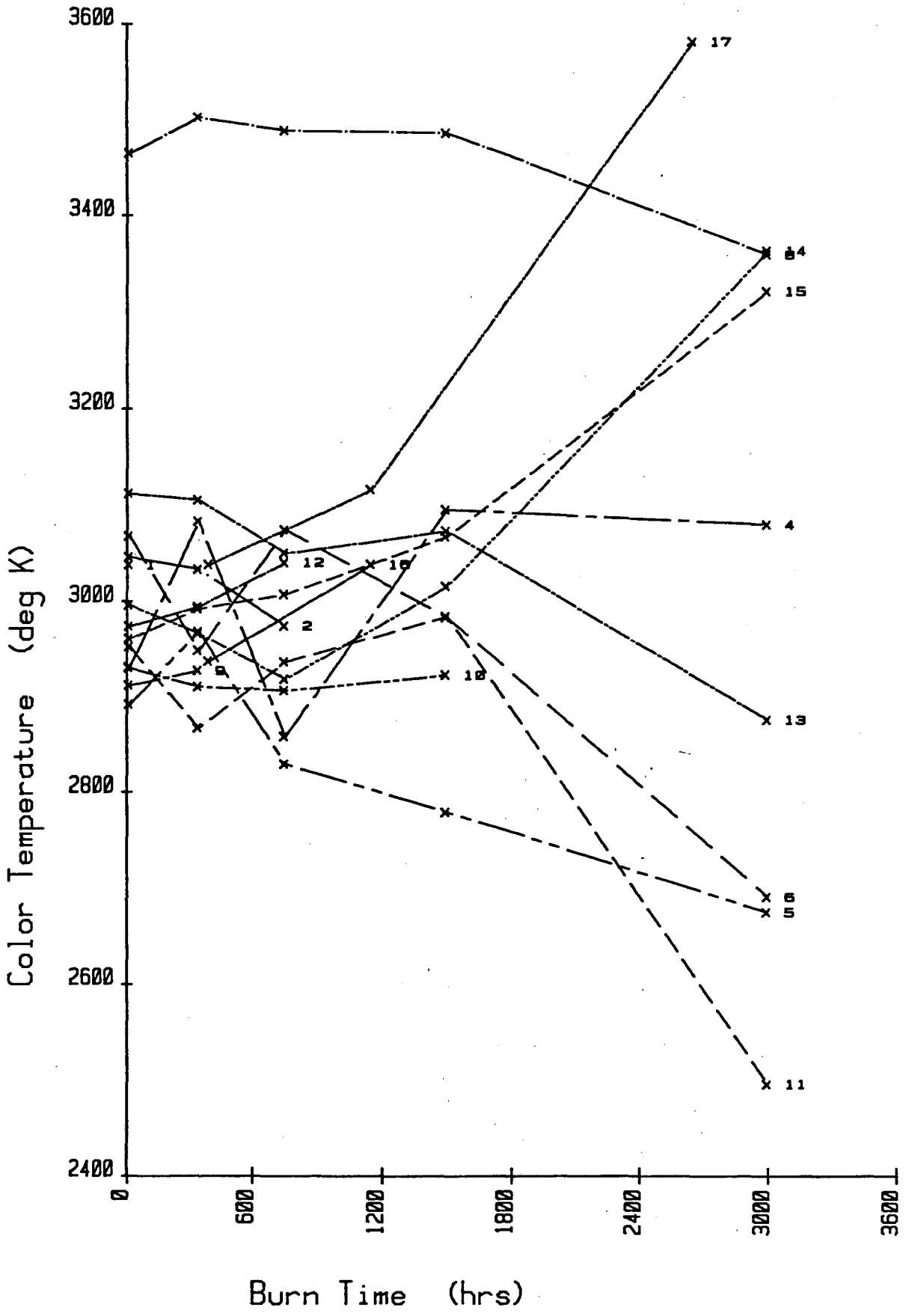
GRAPH 9

GE HALARC LIFE TEST DATA
COLOR RENDERING INDEX vs BURN TIME



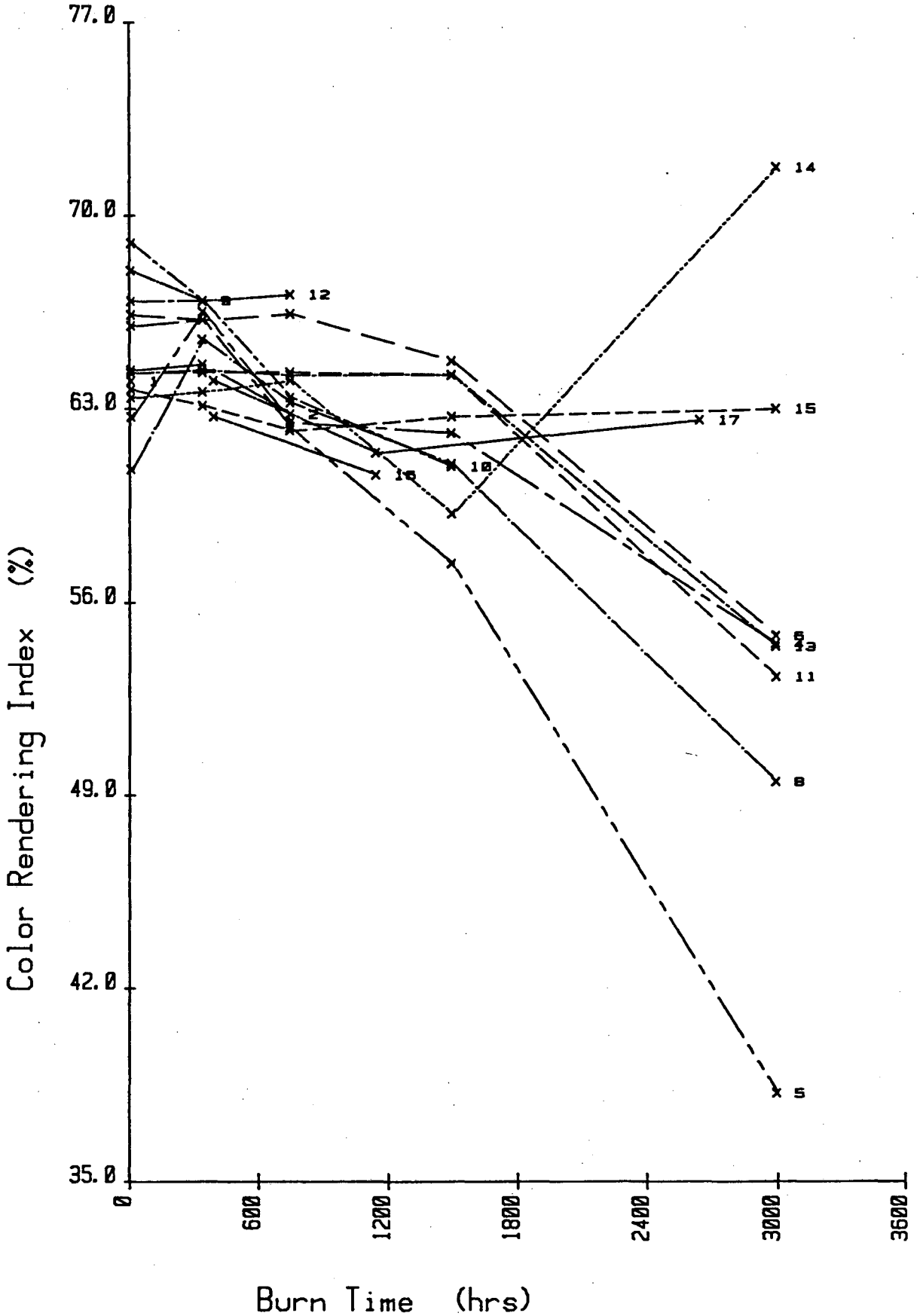
GRAPH 10

GE HALARC LIFE TEST DATA
COLOR TEMPERATURE vs BURN TIME



GRAPH 11

GE HALARC LIFE TEST DATA
COLOR RENDERING INDEX vs BURN TIME



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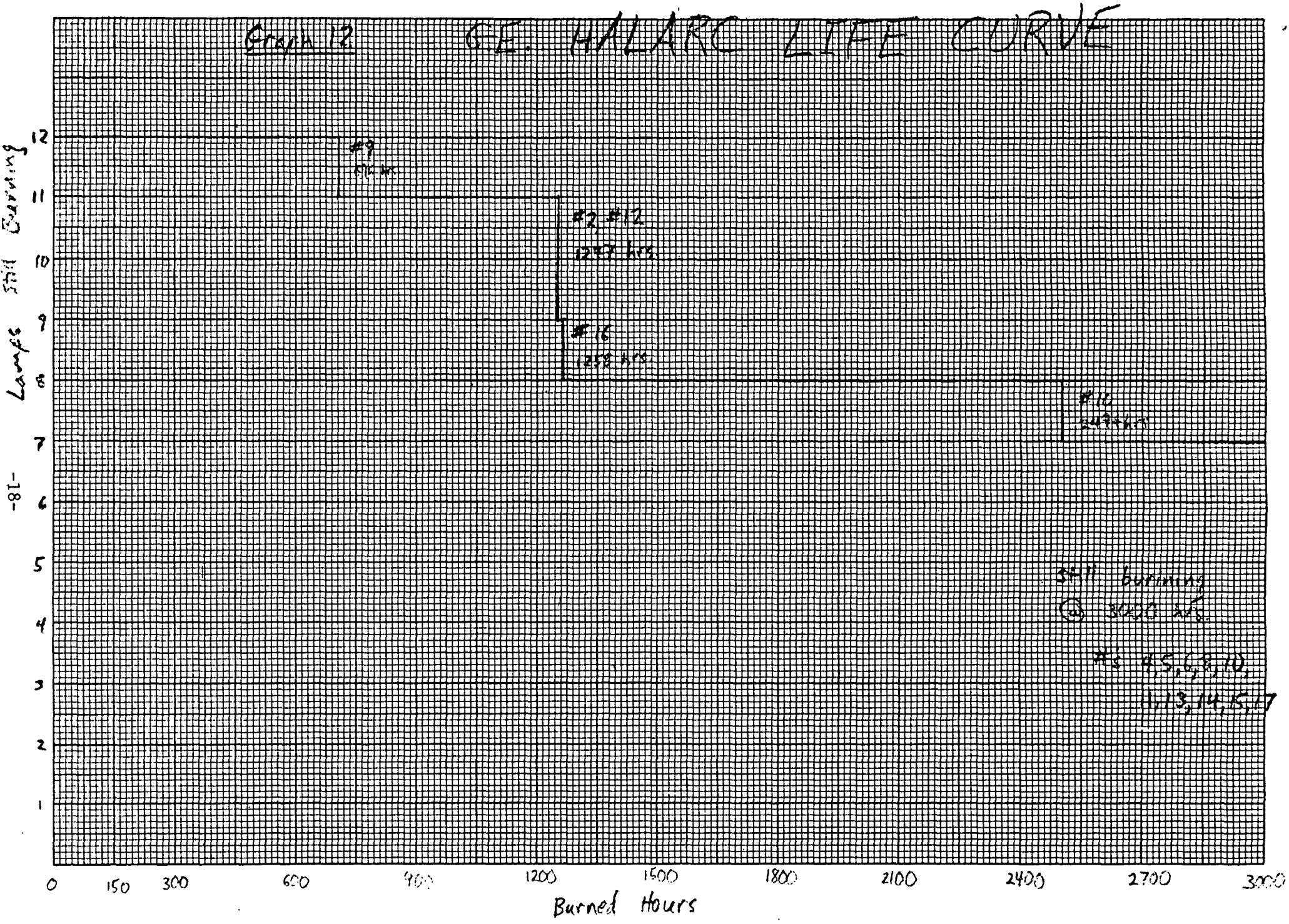


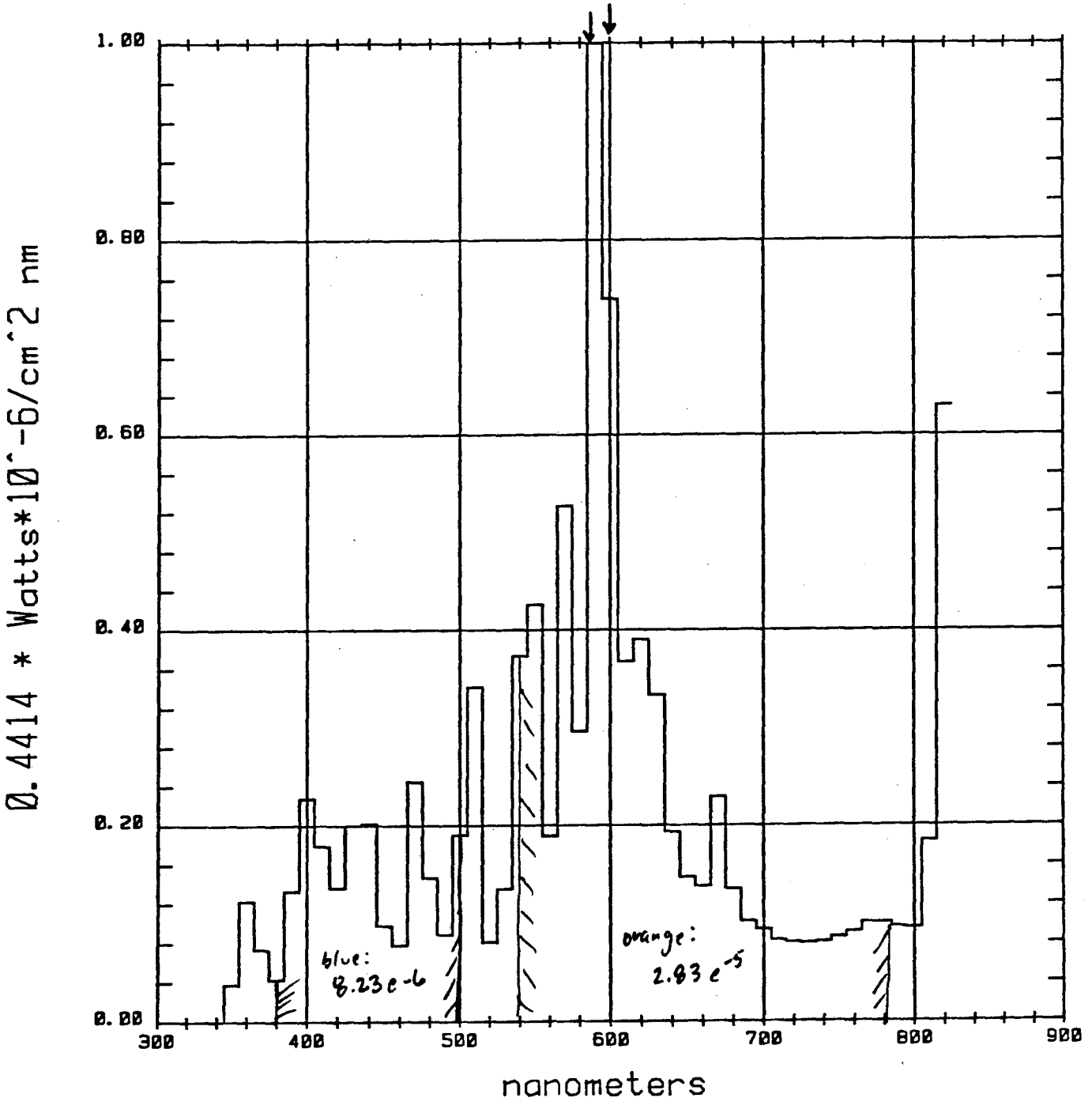
Graph 13

SPECTRAL IRRADIANCE MEASUREMENT

LAMP TYPE:Halarc #GE11 Comment:1/2 Hr. warm up time
OP:L.Leung DATE:6/9/82

10nm MEAS. INC.
Sum from 350 to 800nm= 4.122E-05 Watts/cm^2
Lumens per square foot(Footcandles)= 1.095E 01
x=0.4341 y=0.3959 u=0.2523 v=0.3451 C.C.T.(Kelvin)= 2984 mired= 335.2
General color rendering index (Ra)= 64.2
R(9)=$$$$$ R(10)= 60.4 R(11)= 62.4 R(12)= 79.7 R(13)= 59.8 R(14)= 91.2

GE #11 @ 1500 hrs

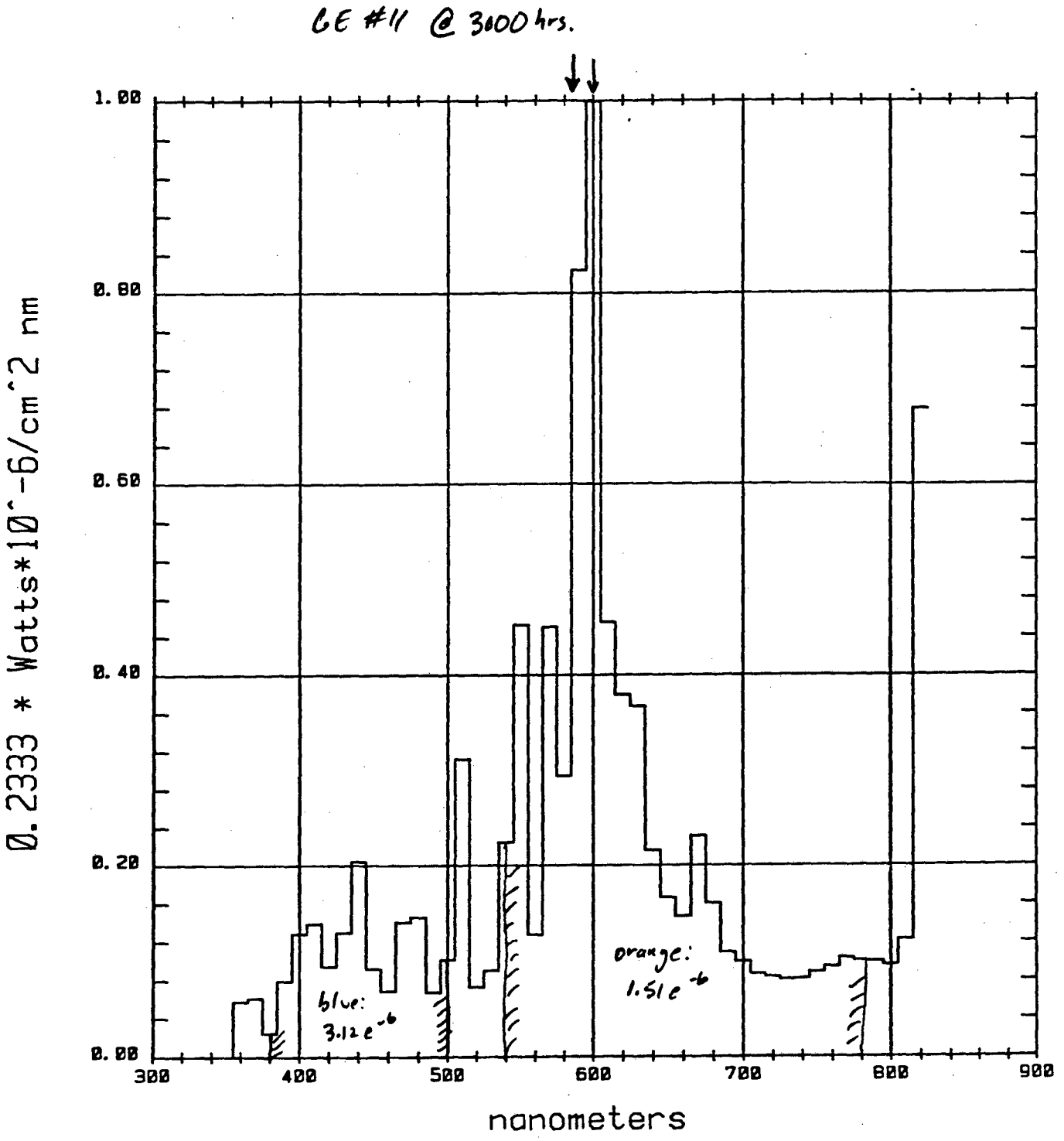


SPECTRAL IRRADIANCE MEASUREMENT

Graph 14

LAMP TYPE:G.E. Halarc #11 Comment:1/2 Hr. warm up time
OP:L.Leung DATE:8/18/82

10nm MEAS. INC.
Sum from 350 to 800nm= 2.013E-05 Watts/cm^2
Lumens per square foot(Footcandles)= 5.392E 00
x=0.4639 y=0.3919 u=0.2739 v=0.3471 C.C.T.(Kelvin)= 2496 mired= 400.6
General color rendering index (Ra)= 53.3
R(9)=$$$$$ R(10)= 51.6 R(11)= 56.7 R(12)= 84.0 R(13)= 47.2 R(14)= 81.3



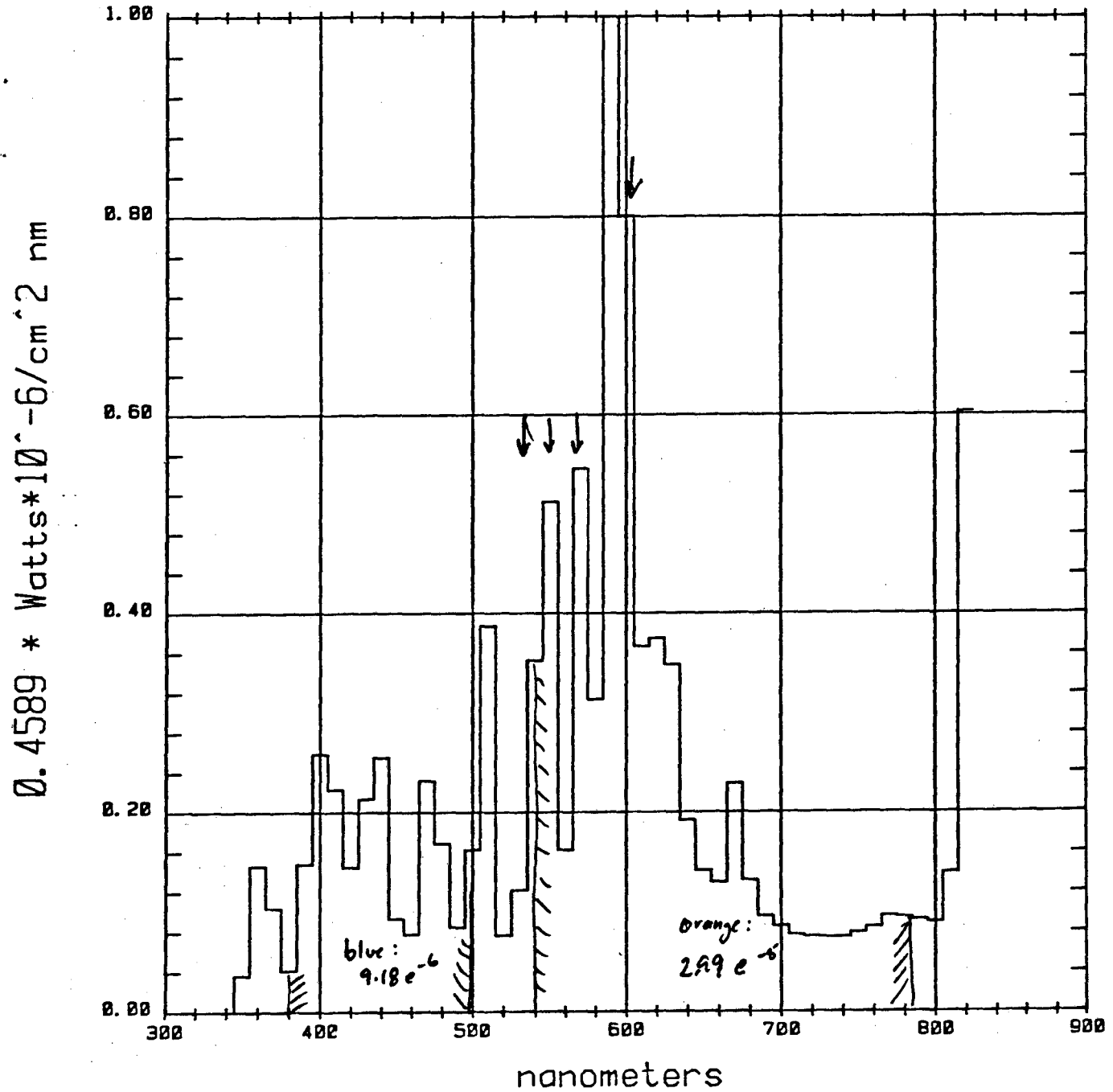
SPECTRAL IRRADIANCE MEASUREMENT

Graph 15

LAMP TYPE:GE15 Comment:Over .5Hr warm up time
OP:L.Leung DATE:4/21/82

10nm MEAS. INC.
Sum from 350 to 800nm= 4.407E-05 Watts/cm^2
Lumens per square foot(Footcandles)= 1.170E 01
x=0.4312 y=0.3929 u=0.2517 v=0.3440 C.C.T.(Kelvin)= 3007 mired= 332.6
General color rendering index (Ra)= 62.2
R(9)=$$$$$ R(10)= 55.2 R(11)= 61.6 R(12)= 77.4 R(13)= 55.8 R(14)= 89.8

GE #15 @ 750hrs



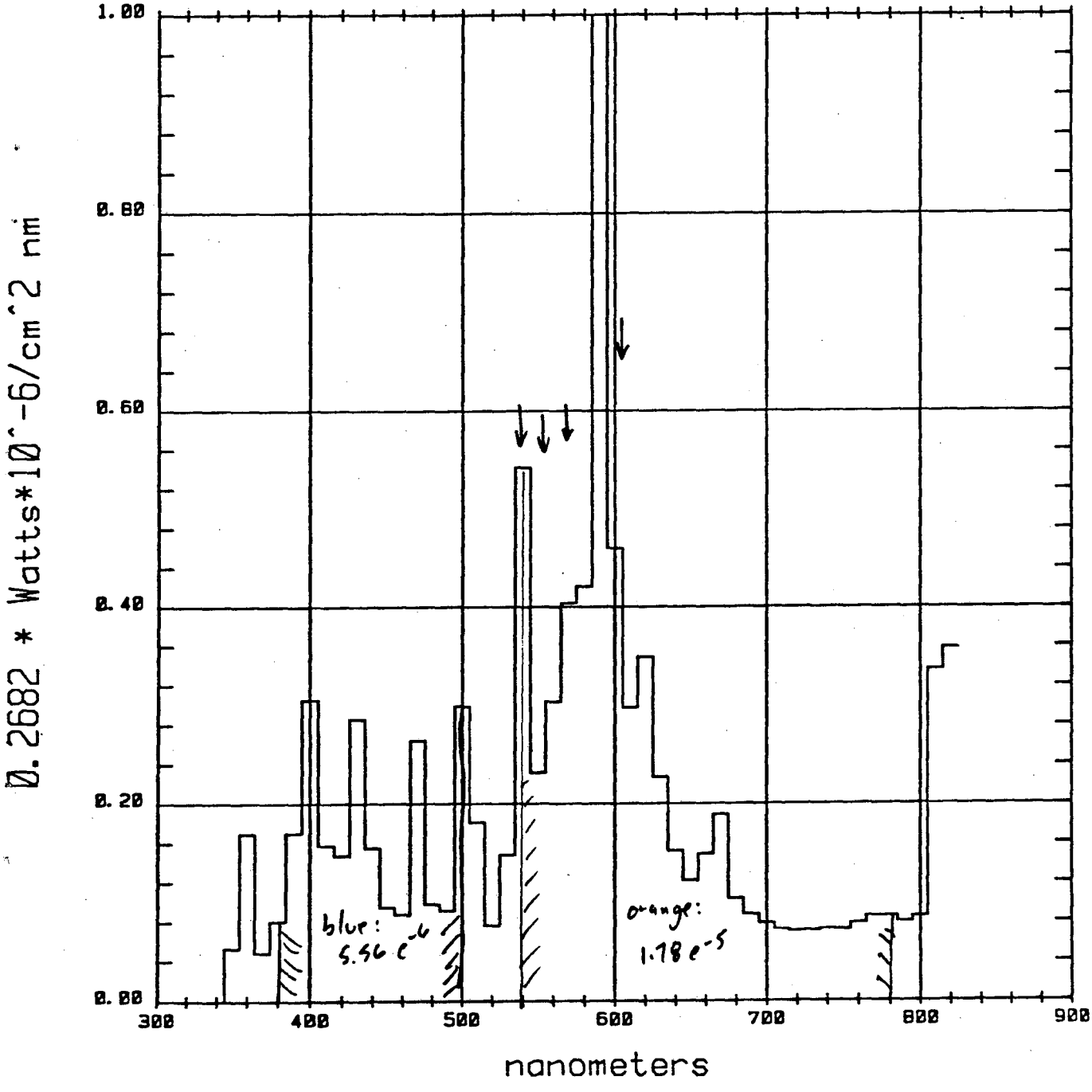
SPECTRAL IRRADIANCE MEASUREMENT

Graph 16

LAMP TYPE:G.E.Halarc #15 Comment:1/2 Hr. warm up time
OP:L.Leung DATE:8/19/82

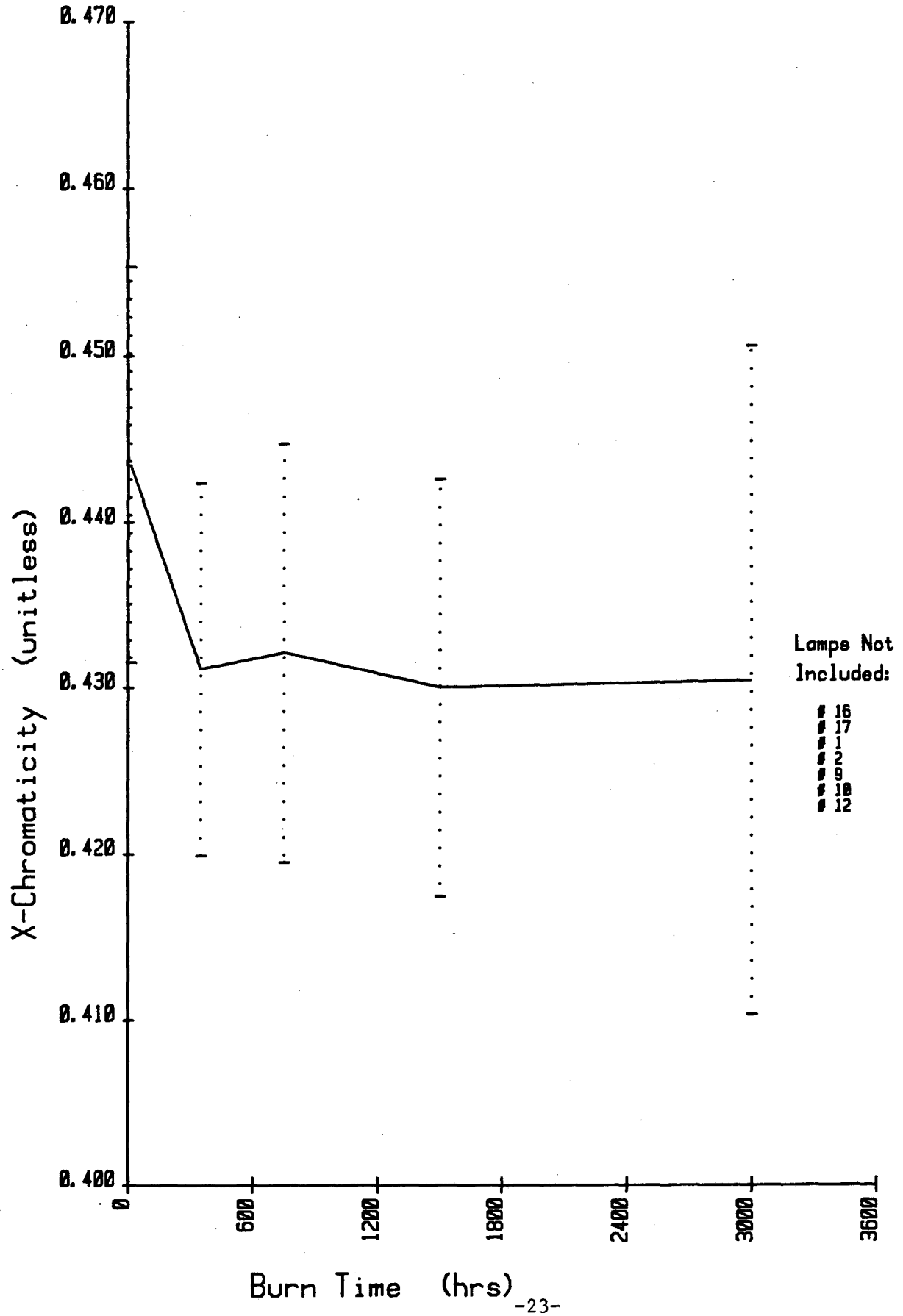
10nm MEAS. INC.
Sum from 350 to 800nm= 2.360E-05 Watts/cm^2
Lumens per square foot(Footcandles)= 6.252E 00
x=0.4163 y=0.3972 u=0.2401 v=0.3437 C.C.T.(Kelvin)= 3322 mired= 301.0
General color rendering index (Ra)= 63.0
R(9)=$$$$$ R(10)= 60.7 R(11)= 50.0 R(12)= 66.6 R(13)= 65.3 R(14)= 93.6

GE #15 @ 3000hrs.



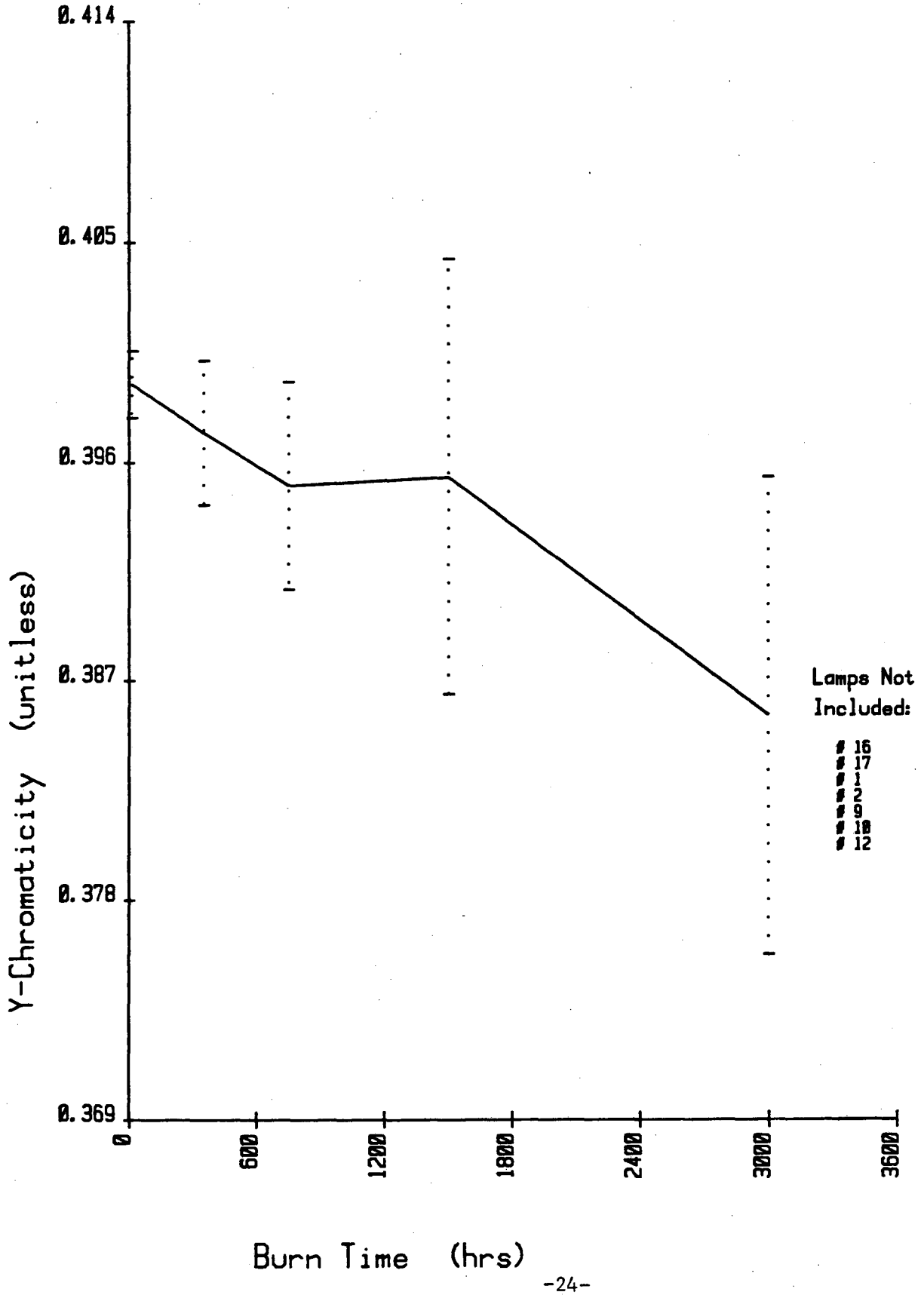
GE HALARC LIFE TEST DATA
X-CHROMATICITY vs BURN TIME

Graph 17



Graph 18

GE HALARC LIFE TEST DATA
Y-CHROMATICITY vs BURN TIME



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