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# The usability of tungsten halogen lamps as secondary standards of luminous intensity

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# THE USABILITY OF TUNGSTEN HALOGEN LAMPS AS SECONDARY STANDARDS OF LUMINOUS INTENSITY

by
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## ABSTRACT

Tungsten halogen lamps are widely used as sources of radiant intensity because of their compactness and long life. Little is known, however, about their usefulness as secondary standards of radiant intensity. What is unknown is the polar distribution of the emitted light. If it is irregular in space, it may be possible to use a frosting as a means of providing for a more uniform distribution. In addition, use of a black sleeve over the lamp may be used to control emitted light, and also control the temperature of the lamp.

To perform the experiment, a lampholder was designed and constructed, which allows the lamp to be moved on its horizontal and vertical axis. The lampholder was set up on an optical bench along with a foot-candle meter, for lamp testing. Using this set up a clear lamp, and lamps frosted by mechanical buffing and acid treatement were tested for direction characteristics. A black sleeve was designed and constructed and tested with the machine frosted lamp. Experimentation shows favorably tward the fact that a machine frosted lamp can be used as a secondary standard.

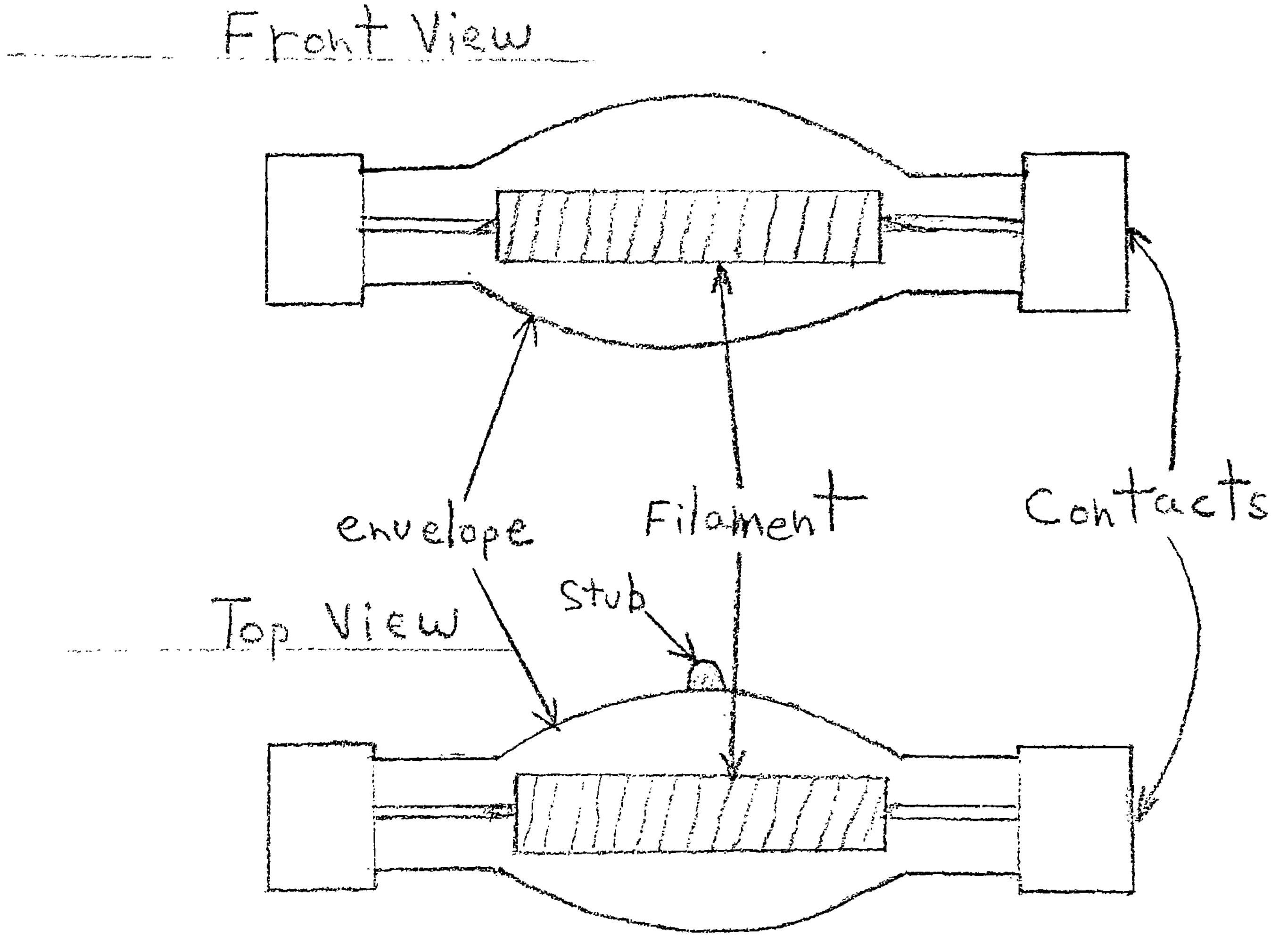
# INTRODUCTION

Tungsten halogen lamps are a kind of tungsten lamp. They consist of a tungsten filament in a quartz or glass tube containing halogen vapor. The halogen sets up a regenerative cycle by which evaporated tungsten is removed from the bulb and returned to the filament. This complex tungsten halogen cycle will function when the bulb wall is 250 $^{o}$F or more. This is achieved by using a small bulb. This makes it possible to produce smaller size lamps with higher light output and longer life than traditional tungsten lamps of the same wattage.

Tungsten halogen lamps are made both as rounded bulbs and in tubular form. They are supplied in power ranges of from 50 watts to 2000 watts, and with color temperatures ranging from 2500 degrees Kelvin to 3400 degrees Kelvin. Tungsten halide lamps have the advantage of consistent color temperature throughout their life. There is more UV radiation produced because of higher filament temperature combined with a transparent quartz envelope. The filament type used is a single coil, or a coiled coil. In general, as the voltage across the lamp increases, color temperature increases and the filament life is shortened.

The lamps used in this experiment were General Electric Quartzaline 150 watt tungsten halogen type, with electrical contacts on each end, as shown in figure 1.

FIGURE I



# INTRODUCTION

The dimensions of the lamp are six centimeters long by one and one half centimeters wide, which is indeed compact for a 150 watt lamp. According to my orientation, each lamp has a small stub on the back of its envelope and directly behind its filament. These stubs were used adventageously to position the lamp in the lamp holder.

The first task I performed was the design and construction of a lampholder with the proper electrical lamp recepticle. The first model was built of wood and painted black. It included a base which could ride on an optical bench and a stationary lamp recepticle. The idea behind this setup was the use of a movable foot candle meter sensor with the stationary lampholder on an optical bench. Moving the sensor about the horizontal and vertical axes of the lamp would determine the direction characteristics of the lamp. This method was aborted because of the obvious difficulty in obtaining accurate degree measures of the lamp in many planes. I decided, then, to modify the lampholder to contain horizontal and vertical degree scales and movement, so that the lamp could be moved and the direction angle of the lamp accurately measured. The lampholder was modified as described. The first attempts at using the modified lampholder exposed another problem, wood surfaces near to the lamp were too suseptible to the heat of the lamp. To combat

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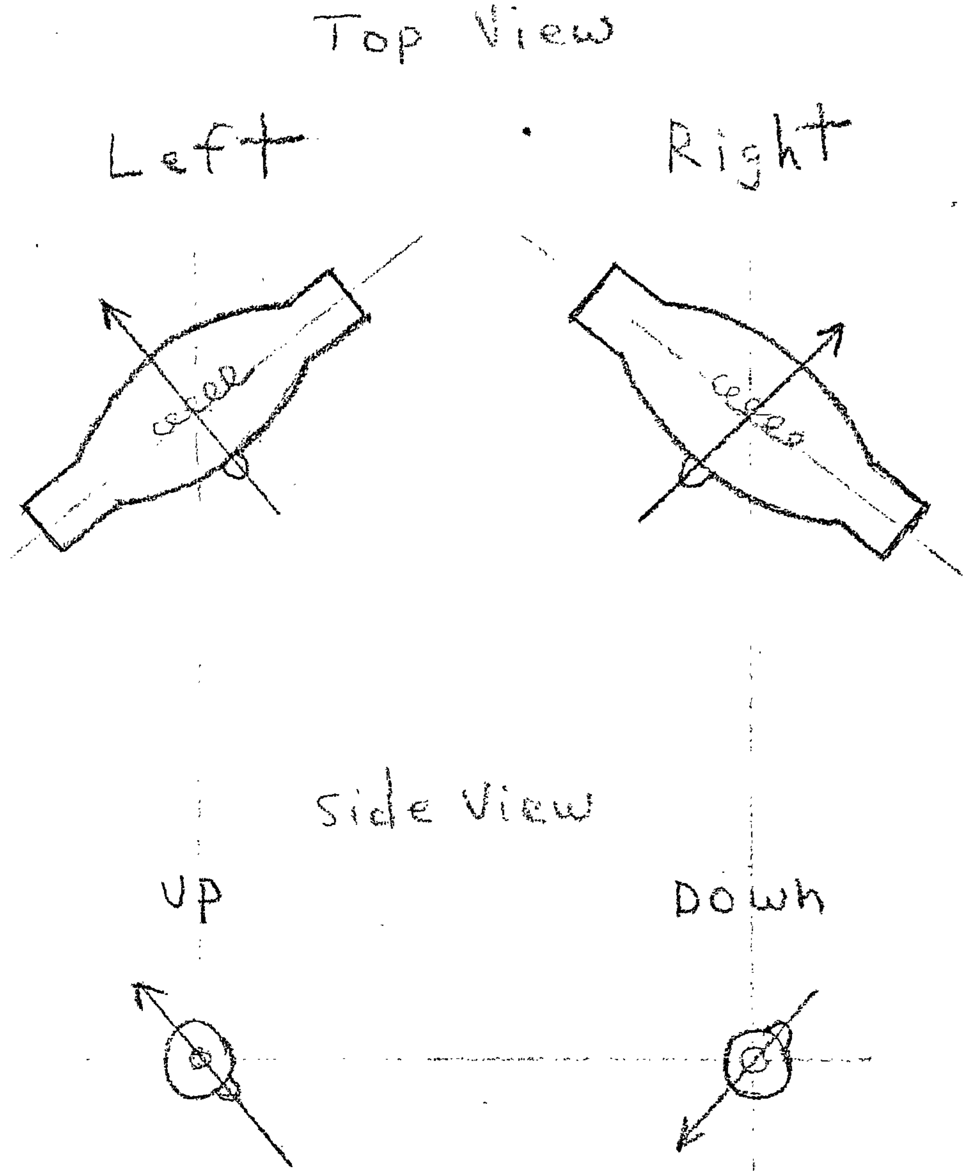
this problem, further modifications of the lamp receptICLE itself were made by moving wood surfaces further away from the lamp, otherwise the lampholder was unchanged. The design of the lampholder is such that the lamp is moved horizontally and vertically about pivots which run through the center of the filament. The direction angle of the lamp is indicated on protractor-like scales as the lamp is moved about these pivots. The notation I use in describing the direction of the lamp is up, down, left or right, and the degree measure in that direction. A couple of examples are; up 10 degrees, right 30 degrees, and so on. Figure two describes this notation, and figure three is a drawing of the degree scales and pivots. Figure four is a drawing of the lampholder.

At last, the task of actually frosting a lamp has arrived. There exist two methods of frosting a glass surface, one is by some physical means, such as sand paper or grinding wheel, the other is by chemical means such as acid treatement. I first explored a physical means of frosting. For experimentation purposes, several squares of glass were cut from a large piece of regular window glass. Many, many means of frosting were explored, sand paper, files etc.. None of them proved worthy. The major problems were that the frosting was too coarse,

FIGURE 2

# Lamp Notation

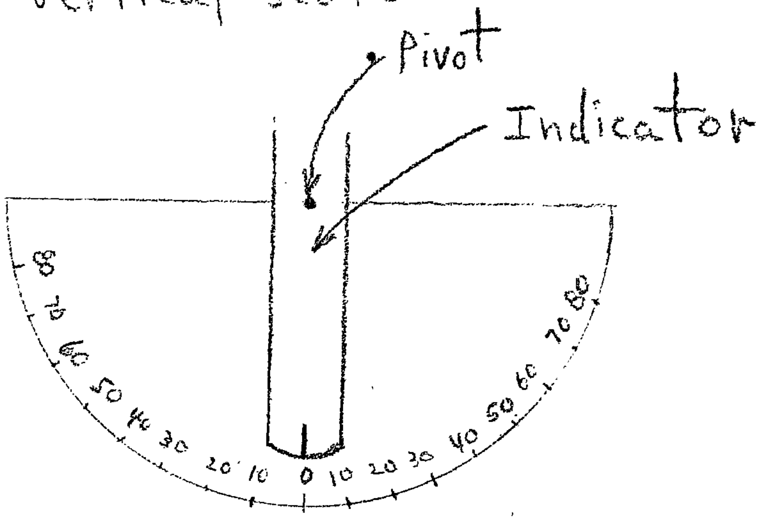



Note: Centers of lamps are pivot points

FIGURE 3

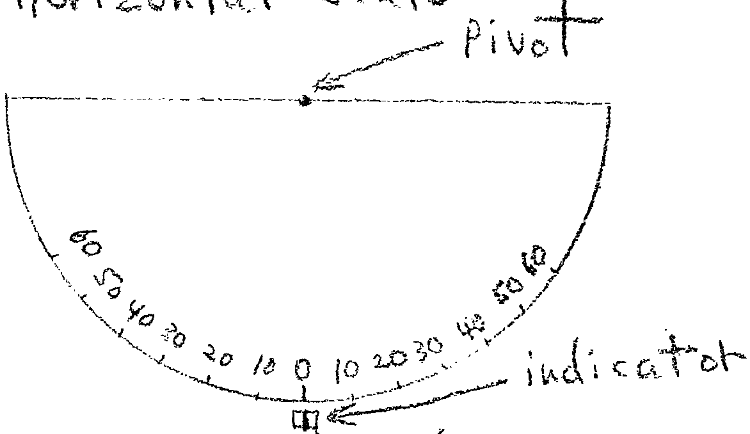
# Degree Scales and Pivots

## Vertical Scale



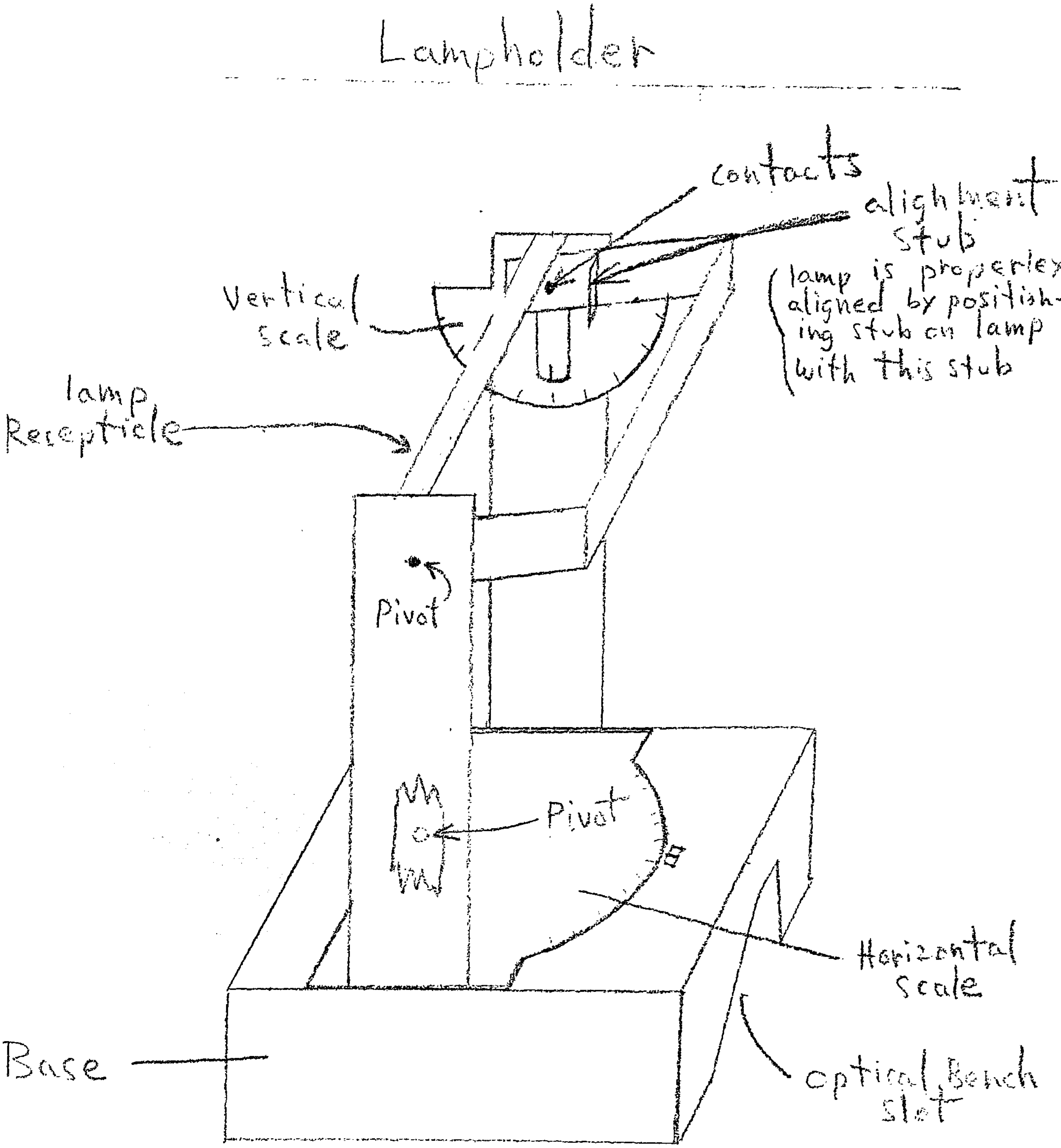

Scale Measures 0 to 80 degrees in increments of 10 degrees

## Horizontal Scale




Scale measures 0 to 60 degrees in increments of 10 degrees

FIGURE 4


Lampholder
contacts
alighment
Stub
lamp is properley
aligned by positish-
ing stub on lamp
with this stub
Vertical
scale
lamp
Recepticle
Pivot
Pivot
Horizontal
scale
Base
optical Bench
slot

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and a great deal of work was required to achieve just a small amount of frosting. I turned next to the use of a machine as a means of frosting. I thought about using a grinding wheel, however, this seemed barbaric and could easily have destroyed the lamp, so I made that method one of my last choices. The method that I did use, and which proved to work very well, is a buffing wheel on which buffing rouge had been applied. The rouge is a sand-like grit material and the buffing wheel consisted of several layers of soft cloth formed into a wheel. Frosting glass by this method is easy, the rouge is applied on the wheel, the buffing machine turned on, and the glass surface held firmly against the wheel and moved slowly around, to obtain even frosting over the entire surface. Using this method, the first lamp, lamp number one, was frosted. Upon examining the lamp, the filament can be detected, but windings of the filament cannot be distinguished. The frosting itself is composed of many very fine scratches on the glass surface. The next task I wanted to perform was frosting a lamp by acid treatement, as this method may also produce an excellent frosting, and possibly one which is superior to machine frosting. The acid to be used is hydrofluoric because of its high glass etching ability. The standard procedure involves first coating, with wax, the parts of the lamp that you don't want the acid to act upon. In my case it was the metal

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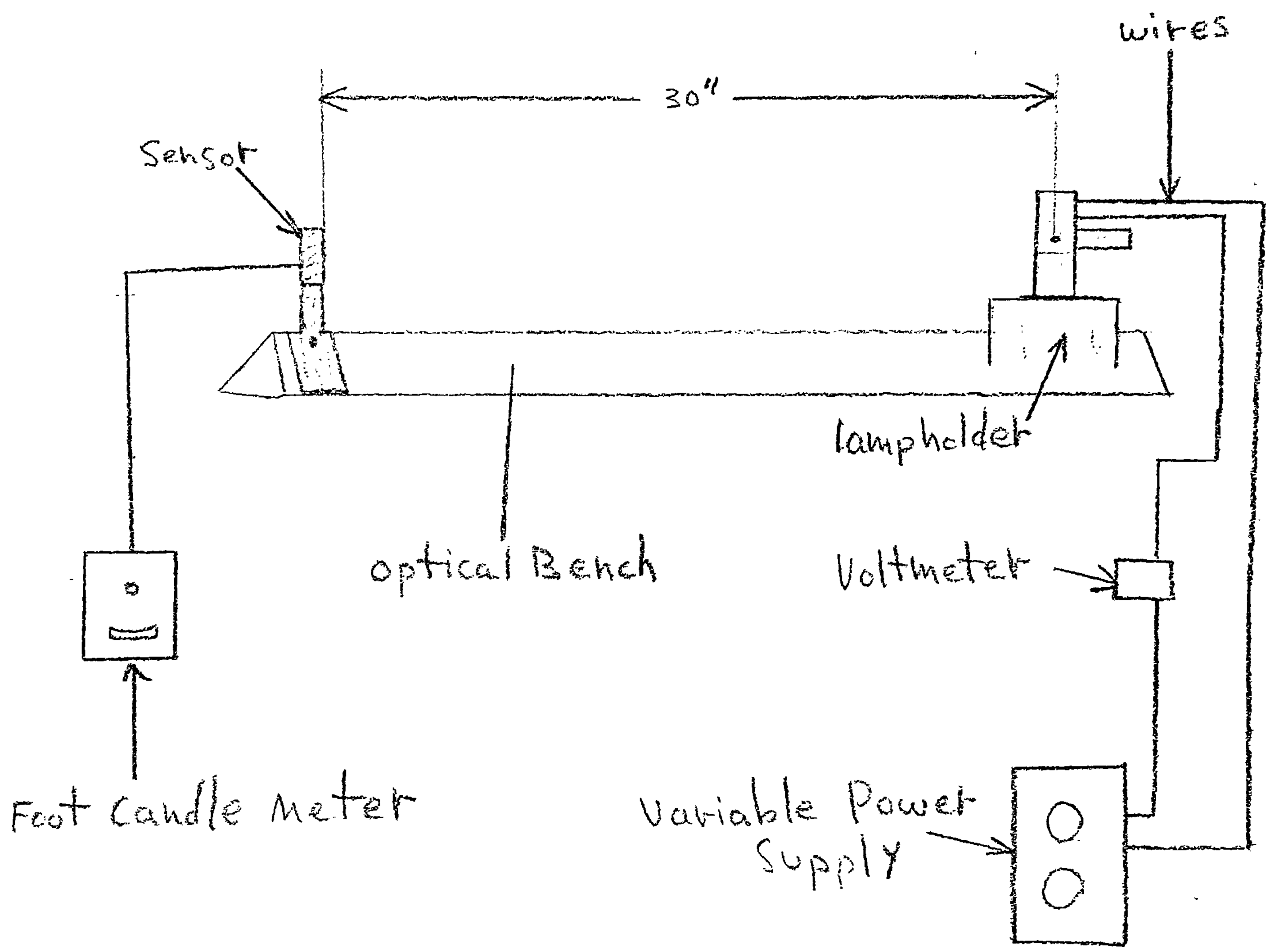
contact ends of the lamp. I also constructed an emersing device to easily facilitate removing and replacing the lamp in the acid container. This was made from stiff wire, and also coated with wax. From previous testing of the acid on regular window glass, I figured that it would take approximately three hours to frost a lamp satisfactorally. About eight ounces of the acid were put into a plastic beaker and set under the hood in the chemistry lab. Lamp number two was attached to the emersing device and placed in the beaker. The lamp was clocely observed for three hours, after which only a very small amount of etching could be seen. With that observation, I decided to leave the lamp in the acid overnight, and remove it the next morning. When I returned the next morning, the lamp had dissolved, all except the filament.

This left only one untreated lamp remaining, lamp number three. Before attempting any frosting of this lamp, I tested it for direction characteristics so that I would have data from a standard clear lamp that I could compare to data from the frosted lamps. This lamp could be frosted later on anyway. The set up is shown in figure five, which included the lampholder and foot candle meter sensor mounted on an optical bench. The distance between them was chosen at random to be 30 inches. The sensor was modified by placing a slit over it. The slit size is 2mm by 5mm, because that is

FIGURE 5

Lamp Testing Set Up



the size of the lamp filaments. The slit was also designed so that when it is placed on the sensor, the slit is in the center of the sensor surface. The power supply used was the variable type, with coarse and fine adjustments. A voltmeter was placed in the circut with the lamp and power supply so that the voltage could be accurately adjusted to 25 volts, which is recommended for the lamps. Using this set up, lamp number three was inserted and properley aligned in the lampholder, and tested. First the slit factor was determined by reading the illumination with and without the slit on the meter sensor, then the lamp was tested for direction characteristics. This data appears in table one. With this data obtained, I could again attempt acid frosting, using lamp number three. This was done exactly as before, except this time the lamp recieved almost constant attention. After being submerged in hydrofluoric acid for six hours, satisfactory etching was achieved. The frosting appears as small bubbles on the glass surface. The treatement seems to make the glass envelope more transparent and distorts the image of the filament.

Using the previously mentioned testing set up, lamp number one (machine frosted) was tested. The data looked good, so I attempted modifying the frosting by lightly stroking over it with a hand file, particularly over areas where the frosting looked non-homogenious.

# TABLE 1, LAMP # 3, CLEAR

without slit 155.00 ft-candle
with slit 3.60 ft. candle

$$\text{Slit Factor} = \frac{155.00}{3.60} = 43.06$$

| | | Left 50 | 40 | 30 | 20 | 10 | 0 | Right 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Up | 50 | 3.10 | 3.61 | 3.82 | 3.91 | 3.89 | 3.99 | 3.89 | 3.77 | 3.98 | 3.92 | 3.58 |
| | 40 | 3.11 | 3.51 | 3.76 | 3.89 | 3.89 | 4.08 | 4.01 | 3.99 | 3.98 | 3.71 | 3.60 |
| | 30 | 3.12 | 3.46 | 3.86 | 3.87 | 3.91 | 4.06 | 4.01 | 3.81 | 3.76 | 3.74 | 3.58 |
| | 20 | 3.08 | 3.29 | 3.48 | 3.67 | 3.77 | 3.81 | 3.80 | 3.71 | 3.65 | 3.63 | 3.59 |
| | 10 | 3.01 | 3.40 | 3.49 | 3.70 | 3.80 | 3.91 | 3.76 | 3.70 | 3.62 | 3.59 | 3.53 |
| | 0 | 3.11 | 3.31 | 3.42 | 3.44 | 3.71 | 3.89 | 3.81 | 3.61 | 3.42 | 3.31 | 3.42 |
| Down | 10 | 2.98 | 3.12 | 3.32 | 3.38 | 3.46 | 3.54 | 3.71 | 3.65 | 3.43 | 3.29 | 3.19 |
| | 20 | 3.12 | 3.21 | 3.34 | 3.46 | 3.49 | 3.60 | 3.73 | 3.61 | 3.52 | 3.41 | 3.22 |
| | 30 | 3.11 | 3.22 | 3.43 | 3.51 | 3.56 | 3.65 | 3.78 | 3.64 | 3.53 | 3.42 | 3.21 |
| | 40 | 3.02 | 3.10 | 3.32 | 3.44 | 3.42 | 3.51 | 3.67 | 3.56 | 3.41 | 3.35 | 3.19 |
| | 50 | 2.91 | 3.01 | 3.11 | 3.39 | 3.42 | 3.52 | 3.71 | 3.65 | 3.42 | 3.21 | 3.11 |

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The lamp was tested again and showed improvements. Data for lamp number one appears in table two. Lamp number three (now acid frosted) was also tested, this data appears in table three.

My next task was to design, and build a sleeve for the lamps. My first ideas included using copper plumbing pipe or sheet metal. After experimenting with the copper pipe I decided to try sheet metal. The pipe proved very heavy and very difficult to work with. Cutting a slit in this material, suitable for use with my lamps, proved almost impossible. The resulting slit is very poor. Inserting the lamp in such a sleeve and maintaining its position was also a problem. Use of sheet metal proved much more profitable, because of the great versitility available when using sheet metal. Using sheet metal, several sleeves were constructed specifically for use with my lamps. The final, and best design I have come up with, is a sleeve made out of sheet metal consisting of three parts, two ends and a central section, as shown in figure six. The lamp is inserted in the central section and the ends slipped on. This makes inserting and holding the lamp in position easy. This sleeve is also light and compact. Another problem I encontered in sleeve construction was the application of a flat black coating on the inside of the sleeve that would not burn up. My solution to this problem was to use a carbon coating applied by inserting the sleeve into a flame. This provides an

TABLE 2

## Lamp 1, Machine Frosting Alone

| | | Left | | | | | | Right | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 40 | 30 | 20 | 10 | 0 | 10 | 20 | 30 | 40 | 50 |
| Up | 50 | 3.21 | 3.41 | 3.48 | 3.49 | 3.47 | 3.48 | 3.46 | 3.42 | 3.31 | 3.66 | 3.57 |
| Up | 40 | 3.20 | 3.51 | 3.52 | 3.53 | 3.51 | 3.54 | 3.52 | 3.53 | 3.50 | 3.52 | 3.54 |
| Up | 30 | 3.15 | 3.22 | 3.51 | 3.53 | 3.55 | 3.57 | 3.66 | 3.58 | 3.50 | 3.51 | 3.54 |
| Up | 20 | 3.23 | 3.27 | 3.51 | 3.54 | 3.56 | 3.59 | 3.61 | 3.55 | 3.51 | 3.54 | 3.55 |
| Up | 10 | 3.22 | 3.30 | 3.52 | 3.52 | 3.52 | 3.51 | 3.52 | 3.53 | 3.52 | 3.53 | 3.54 |
| | 0 | 3.19 | 3.21 | 3.53 | 3.52 | 3.52 | 3.52 | 3.52 | 3.52 | 3.54 | 3.53 | 3.60 |
| Down | 10 | 3.20 | 3.30 | 3.51 | 3.52 | 3.51 | 3.51 | 3.52 | 3.52 | 3.51 | 3.56 | 3.61 |
| Down | 20 | 3.21 | 3.40 | 3.53 | 3.51 | 3.52 | 3.52 | 3.51 | 3.51 | 3.52 | 3.54 | 3.67 |
| Down | 30 | 3.23 | 3.54 | 3.55 | 3.52 | 3.51 | 3.51 | 3.51 | 3.52 | 3.53 | 3.59 | 3.65 |
| Down | 40 | 3.10 | 3.40 | 3.41 | 3.42 | 3.41 | 3.42 | 3.47 | 3.41 | 3.41 | 3.47 | 3.47 |
| Down | 50 | 2.04 | 3.21 | 3.34 | 3.40 | 3.33 | 3.38 | 3.40 | 3.40 | 3.39 | 3.40 | 3.40 |

TABLE 2 CONTINUED

Lamp 1, Modified Machine Frosting

| | | Left | | | | | | | | | Right |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 50 | 40 | 30 | 20 | 10 | 0 | 10 | 20 | 20 | 40 | 50 |
| Up | 50 | 3,32 | 3.49 | 3.48 | 3.48 | 3.47 | 3.48 | 3.47 | 3,42 | 3,33 | 3,59 | 3.56 |
| | 40 | 3.31 | 3,57 | 3,51 | 3,50 | 3,51 | 3,57 | 3,52 | 3.57 | 3,51 | 3.54 | 3.54 |
| | 30 | 3,27 | 3.42 | 3.51 | 3.52 | 3,53 | 3.54 | 3.54 | 3.52 | 3.52 | 3.53 | 3.55 |
| | 20 | 3.34 | 3.37 | 3.51 | 3,52 | 3.57 | 3.54 | 3.54 | 3,53 | 3.52 | 3.52 | 3.55 |
| | 10 | 3,33 | 3,47 | 3,52 | 3,52 | 3,52 | 3,52 | 3,52 | 3.52 | 3,51 | 3.52 | 3.54 |
| | 0 | 3,31 | 3.31 | 3,52 | 3,51 | 3,52 | 3,52 | 3.52 | 3.52 | 3.57 | 3,55 | 3.60 |
| Down | 10 | 3,31 | 3.29 | 3,51 | 3,52 | 3,57 | 3.52 | 3.52 | 3.51 | 3.51 | 3.58 | 3.62 |
| | 20 | 3.32 | 3.39 | 3.51 | 3.52 | 3,57 | 3.52 | 3.52 | 3,51 | 3.52 | 3.55 | 3.57 |
| | 30 | 3.44 | 3.54 | 3.57 | 3.51 | 3.51 | 3,57 | 3,51 | 3,52 | 3,51 | 3.57 | 3,47 |
| | 40 | 3.21 | 3,52 | 3.41 | 3.47 | 3,43 | 3.40 | 3.40 | 3,52 | 3.52 | 3.42 | 3.41 |
| | 50 | 2,21 | 3.41 | 3,39 | 3.40 | 3,33 | 3,37 | 3.41 | 3,41 | 3,40 | 3,42 | 3,41 |

TABLE 3

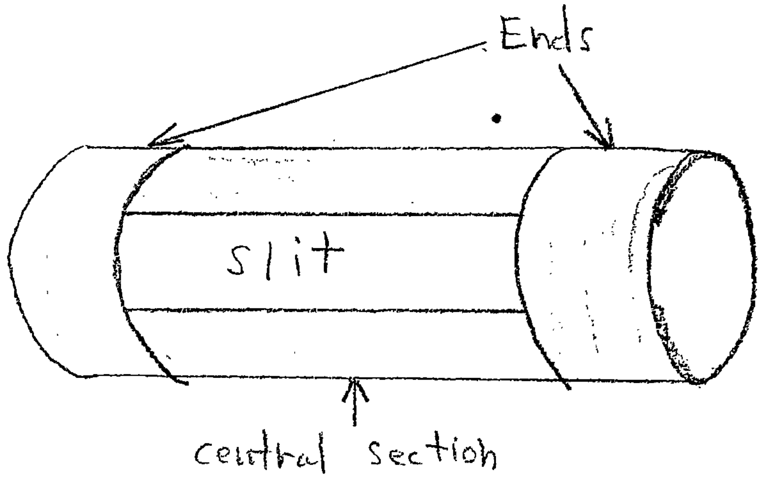
## Lamp #3, Acid Frosted

| | 50 | 40 | 30 | 20 | 10 | 0 | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 | 3.01 | 3.67 | 3.90 | 3.88 | 3.89 | 4.01 | 3.91 | 3.91 | 4.10 | 3.91 | 3.60 |
| 40 | 3.04 | 3.78 | 3.88 | 3.89 | 3.76 | 4.06 | 3.89 | 3.88 | 4.11 | 3.81 | 3.53 |
| 30 | 3.09 | 3.70 | 3.89 | 3.74 | 3.61 | 4.08 | 3.86 | 3.83 | 4.12 | 3.77 | 3.50 |
| 20 | 3.10 | 3.54 | 3.53 | 3.56 | 3.61 | 3.78 | 3.80 | 3.84 | 3.87 | 3.74 | 3.42 |
| 10 | 3.02 | 3.50 | 3.51 | 3.48 | 3.44 | 3.43 | 3.42 | 3.57 | 3.89 | 3.76 | 3.48 |
| 0 | 3.11 | 3.49 | 3.62 | 3.55 | 3.41 | 3.59 | 3.47 | 3.81 | 4.01 | 3.88 | 3.43 |
| 10 | 2.97 | 3.58 | 3.77 | 3.61 | 3.42 | 3.51 | 3.55 | 3.60 | 3.61 | 3.43 | 3.37 |
| 20 | 3.01 | 3.68 | 3.63 | 3.57 | 3.65 | 3.73 | 3.88 | 3.97 | 3.91 | 3.88 | 3.78 |
| 30 | 2.98 | 3.56 | 3.94 | 3.97 | 3.98 | 3.98 | 3.99 | 4.08 | 4.23 | 4.20 | 3.99 |
| 40 | 2.76 | 3.02 | 3.88 | 3.90 | 3.96 | 3.97 | 3.96 | 3.97 | 3.99 | 4.22 | 4.01 |
| 50 | 2.11 | 2.99 | 3.87 | 3.91 | 3.95 | 3.99 | 3.97 | 3.98 | 3.99 | 3.98 | 4.01 |

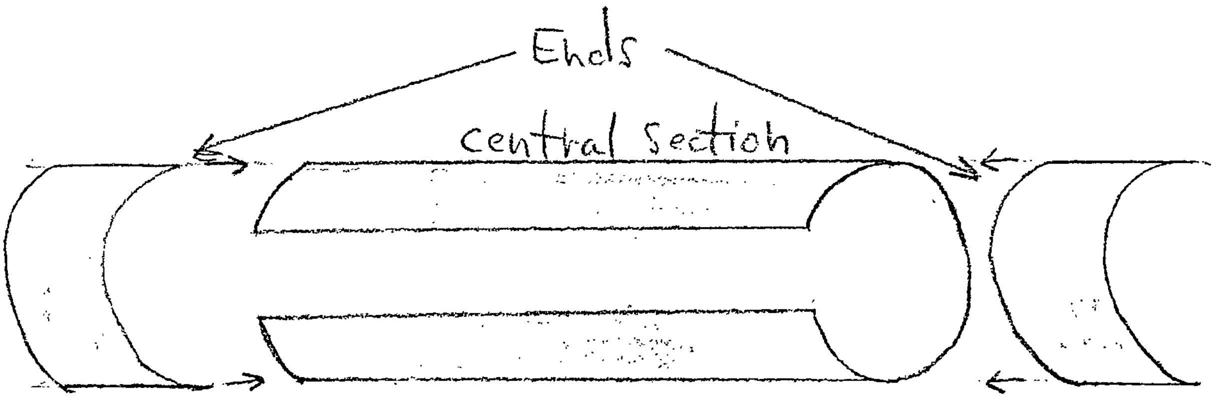
FIGURE 6

# Black Sleeve

Assembeled




Disassembeled




To assemble, ends are slipped on central section as indicated by arrows.

excellent flat black coating that will not respond to the heat of the lamp, however, care must be taken when inserting the lamp to insure that none of the carbon is removed.

Lamp number one was installed in the sleeve and the assembly placed in the lampholder. When testing with the sleeve, the lamp can be moved only from zero to 20 degrees, otherwise the sleeve blocks the light emitted from the lamp. The lamp and sleeve were tested, in the conventional manner, and data gathered, which is in table four.

The next, and final, procedure was to determine if lamp temperature remained constant, and if the black sleeve could be used to control the temperature of the lamps. I chose lamp number one to do this. The lamp was installed in the lampholder and the sensor from an oven-type thermometer placed on it. The thermometer has a sensor that is used in the oven while the indicator registers the temperature outside the oven, therefore the entire thermometer need not be subject to the heat source in question, making it ideal for my use. The lamp was installed in the sleeve and the procedure repeated. table five summarizes the data. When tested with the black sleeve, the lamp blew out, probably because of the elevated temperature within the sleeve.

TABLE 4

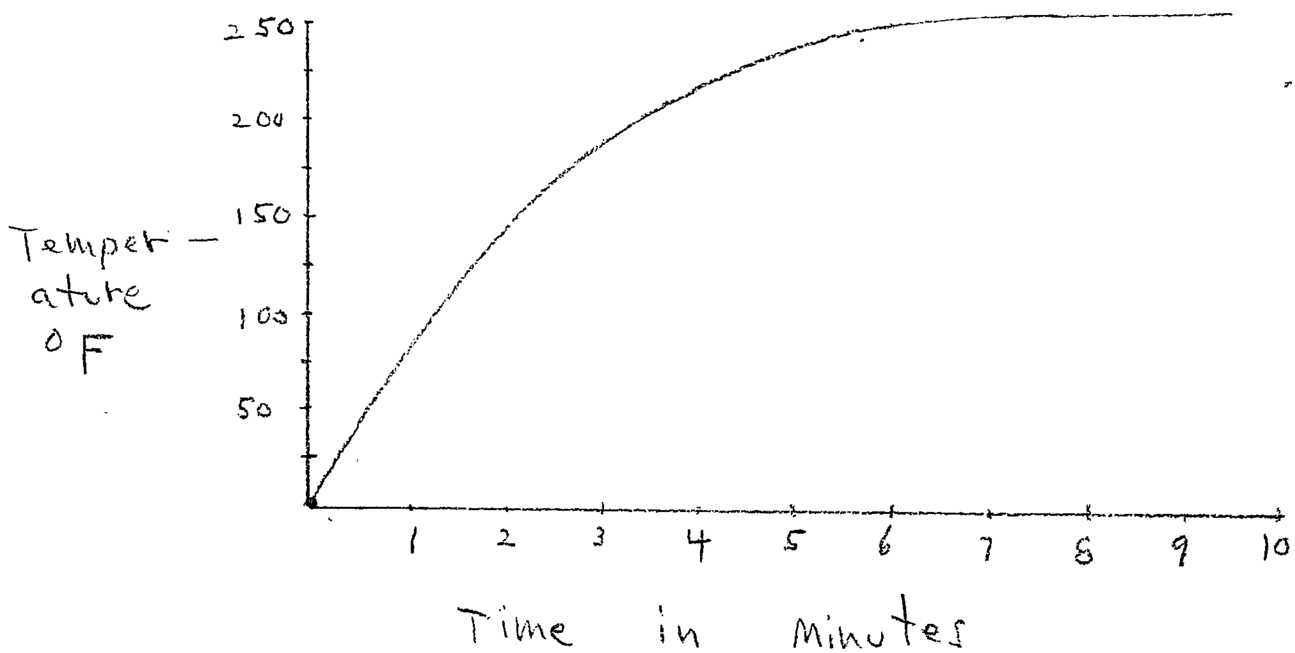
Lamp #1 with Modified Frosting in Sleeve

| | | Left 20 | Left 10 | 0 | Right 10 | Right 20 |
|---|---|---|---|---|---|---|
| Up | 20 | 3,51 | 3,52 | 3,53 | 3,52 | 3,54 |
| | 10 | 3,52 | 3,51 | 3.51 | 3,52 | 3.53 |
| | 0 | 3,52 | 3,51 | 3.51 | 3,51 | 3,51 |
| Down | 10 | 3,51 | 3,51 | 3,51 | 3.51 | 3,53 |
| | 20 | 3.51 | 3.51 | 3,52 | 3.51 | 3.52 |

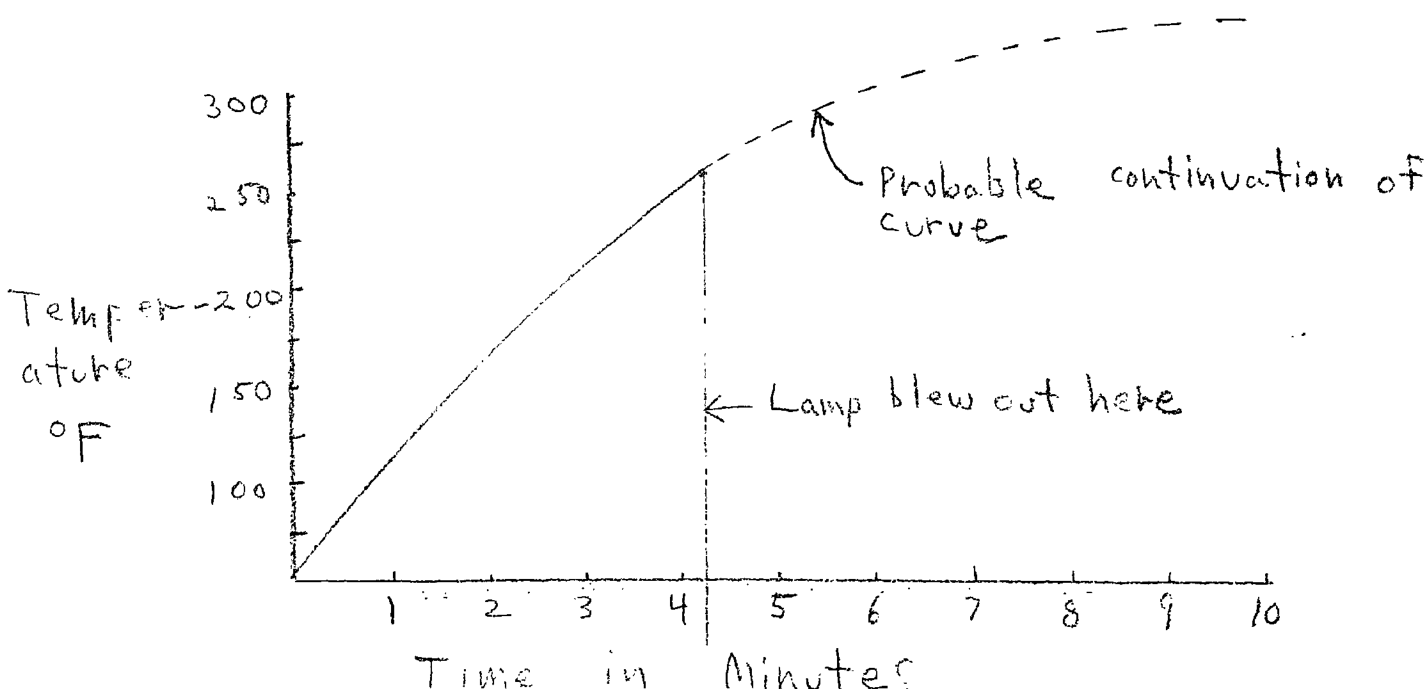
TABLE 5

# Temperature Data

## without sleeve




## with sleeve



## RESULTS

Looking over the data, starting with table one, which is for a non-frosted lamp, one can easily see the need for a frosting. In the critical area, from zero to 20 degrees each way, there is a great deal of fluctuation in the radiant intensity response, in one case it is as much as .60 foot candle. Beyond 20 degrees, there is still a great deal of fluctuation with the illumination falling off to approximately 3.1 foot candles, on the average. Hence, the need for a frosting is established.

The results, from table two, show a remarkable improvement in the response. In the critical area the fluctuations are no greater than .1 foot candle, while, in general, most of the fluctuations are only .01 to .05 foot candles. It is interesting to note that the higher readings of 3.6 foot candles seemed to be concentrated in one area rather than being random. That is what prompted me to try to modify the frosting. The continuation of table two shows that the modifications did improve the results. The lowest reading in the critical area was 3.51 foot candles and the highest was 3.54 foot candles, leaving a difference of only .03 foot candle! Many of the readings were identical. This shows enormous improvement over a non-frosted lamp.

As for the acid frosted lamp, table three shows little improvement over a regular lamp. The response varies as much as .38 foot candle.

# RESULTS

Upon examination of table four, we can see that we have some excellent data. The greatest fluctuation in the response is only .03 foot candle. Another advantage is that the illumination beyond the critical range of 20 degrees has been eliminated by the sleeve. All that remains is highly diffuse illumination. This is the best prospective secondary standard that I have been able to achieve.

Refering to table five, the most obvious difference between the lamp with and without the sleeve is the temperature difference. As can be seen, without the sleeve, the lamp reaches its peak temperature of 250 degrees Farenheit after five minutes. The temperature then remains constsnt at 250 degrees. With the sleeve, the lamp reached a temperature of 265 degrees in just over four minutes, at which point it blew out. This shows, at least, that the use of a sleeve will raise the temperature of the lamp. One can also speculate that, from continuation of the curve, and data from the lamp without the sleeve, that the temperature would rise to and remain constant at approximately 325 degrees, when the sleeve is used. Use of the sleeve does have a significient effect on the temperature of the lamp.

# CONCLUSION

After tabulating the results, Ihave come to the following conclusions:

1. Lamp number one with machine frosting modified by hand filing, and used in the black sleeve, can be used as a secondary standard of radiant intensity, for such applications as in a sensitometer.

2. Lamp number one with machine frosting alone, or with machine frosting modified by hand filing alone cannot be used as a secondary standard.

3. Lamp number three, used with or without acid frosting, cannot be used as a secondary standard.

4. Use of a black sleeve on the lamps can be used to control the temperature and the emitted light of the lamps.