Incandescent Lamp Design & Manufacturing

by David R. Dayton

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PREFACE

This book is intended as a reference guide for the design, manufacturing, test and evaluation of incandescent lamps. The reference material covers microminiature, sub-miniature, miniature and large lamps (GLS) both vacuum and gas-filled.

This book is not a history or in-depth study of incandescent lamps. References for in-depth information are included in each chapter. References include papers, books, patents and available Sylvania Training Programs.

The purpose of this book is a tool box in the same sense that a tool box and tools are useful to a mechanic. The tools are not used all the time, but they are available and critical when needed.

LAMP PERFORMANCE

LAMP OPERATING CHARACTERISTICS AS A FUNCTION OF VOLTAGE VARIATIONS

1.1 Life, Efficiency, and Voltage Relationships: If the voltage applied to an incandescent lamp is varied, there is a resulting change in the filament resistance, temperature, current, watts, light output, efficiency and life. These characteristics are interrelated and one cannot be changed without affecting the others. The following characteristic equations can be used to calculate the effect of a change from the design conditions on lamp performance (capital letters represent normal rated values).

$$\frac{\text{life}}{\text{LIFE}} = \left[\frac{\text{VOLTS}}{\text{volts}}\right]^d$$

$$\frac{\text{lumens}}{\text{LUMENS}} = \left[\frac{\text{volts}}{\text{VOLTS}}\right]^k$$

$$\frac{\text{LPW}}{\text{lpw}} = \left[\frac{\text{VOLTS}}{\text{volts}}\right]^g$$

$$\frac{\text{watts}}{\text{WATTS}} = \left[\frac{\text{volts}}{\text{VOLTS}}\right]^n$$

$$\frac{\text{amperes}}{\text{AMPERES}} = \left[\frac{\text{volts}}{\text{VOLTS}}\right]^t$$

By substitution from above:

$$\frac{\text{life}}{\text{LIFE}} = \left[\frac{\text{LPW}}{\text{lpw}}\right]^b$$

The values of the exponents vary for different lamp types, for different lamp wattages, for various ranges of per cent voltage variation and for different lpw ranges.

LAMP OPERATING CHARACTERISTICS AS A FUNCTION OF VOLTAGE VARIATIONS

The only true way of determining the exponents is to measure lamp characteristics at different voltages and calculate the exponents. The exponent is calculated by dividing the log of the change in one factor by the log of the change in another factor.

For example:

$$\frac{\log \text{ of } \left[\frac{\text{life}}{\text{LIFE}}\right]}{\log \text{ of } \left[\frac{\text{LPW}}{\text{lpw}}\right]} = \text{exponent} \quad b$$

LAMP OPERATING CHARACTERISTICS (CONTD.)

Table I shows approximate values of exponents g, k, n and t for a range of lamp efficiency.

TABLE I

(GAS-FILLED LAMPS)

LPW	g	k	n	t
8	2.38	3.820	1.510	.5148
9	2.26	3.738	1.518	.5197
10	2.15	3.665	1.522	.5241
11	2.07	3.600	1.527	.5282
12	1.99	3.543	1.500	.5319
13	1.92	3.490	1.535	.5353
14	1.86	3.440	1.538	.5385
15	1.80	3.390	1.540	.5415
16	1.75	3.350	1.544	.5443
17	1.70	3.320	1.547	.5470
18	1.66	3.286	1.549	.5495
19	1.62	3.253	1.550	.5519
20	1.59	3.222	1.554	.5542

Exponents g, k, n and t can be measured and calculated from actual test data. Exponents b and d are calculated from properties of tungsten (Table IV and Table V Chapter II) or preferably calculated from actual life test data.

LAMP OPERATING CHARACTERISTICS (CONTD.)

Table II shows approximate values of exponents b and d for vacuum and gas-filled lamps.

TABLE II

LPW	b Gas-Filled	b Vacuum	d Gas-Filled	d Vacuum
8	6.05	5.55	14.4	14.6
9	6.19	5.75	14.0	14.36
10	6.37	5.94	13.7	14.14
11	6.47	6.10	13.4	13.94
12	6.63	6.27	13.2	13.75
13	6.77	6.42	13.0	13.59
14	6.83	6.57	12.7	13.45
15	6.94	6.70	12.5	13.31
16	7.10	6.83	12.4	13.18
17	7.18	6.95	12.2	13.06
18	7.23	7.07	12.0	12.95
19	7.34	7.16	11.9	12.80
20	7.42	7.25	11.8	12.66

Note that exponent d divided by exponent b equals exponent g. Therefore, exponent b can be obtained by measuring lamps and calculating exponent g and taking d from Table II.

LAMP OPERATING CHARACTERISTICS (CONTD.)

Intermediate values of d in Table II can be calculated:

Gas-filled $d = 22.521\ \text{lpw}^{-.21578}$

Vacuum $d = 19.875\ \text{lpw}^{-.1479}$

A few rules of thumb can be developed from the lamp operating characteristics data.

+ 1% lpw	=	-7%	life
+ 1% volts	=	-14%	life
+ 1% current	=	-27%	life
+ 1% volts	=	+3.4%	lumens
+ 1% current	=	+6.4%	lumens

PHOTOMETRIC MEASUREMENTS OF INCANDESCENT LAMPS

UNITS OF MEASUREMENT OF LIGHT

1.2 All units of measurement for light are based on the response of the average human eye. The following are the most common units used:

1. Candlepower

Intensity of light from any source in a particular direction is expressed in candelas. One Candlepower was originally the intensity of a standard wax candle burned under certain prescribed conditions. Presently the intensity of a black body operating at the melting point of platinum is the standard. The National Bureau of Standards establishes and maintains master incandescent standards.

2. Luminous flux

The lumen is the luminous flux emitted in a solid angle of one steradian by a point source having a uniform intensity of one candela.

3. Illuminance

The lux is the illuminance produced by a luminous flux of one lumen uniformly distributed over a surface of one square metre.

MEASUREMENT OF LIGHT

To establish the liminous output of an incandescent lamp, the Lumen output, along with its power input must be measured.

These measurements are made with a photometer. The photometers are spheres with the inside surface coated with a special diffusing

MEASUREMENT OF LIGHT (CONTD.)

paint so as to intergrate the total luminous flux (the amount of light) being emitted from the test light source.

The sphere paint should be as white as possible so as to give a high reflective surface throughout the visible spectral wave length range.

The above conditions are necessary to give all units of flux emitted from the source equal brightness at the measurement window, which is shielded from direct rays by a fixed baffle. See Figure No. 5.

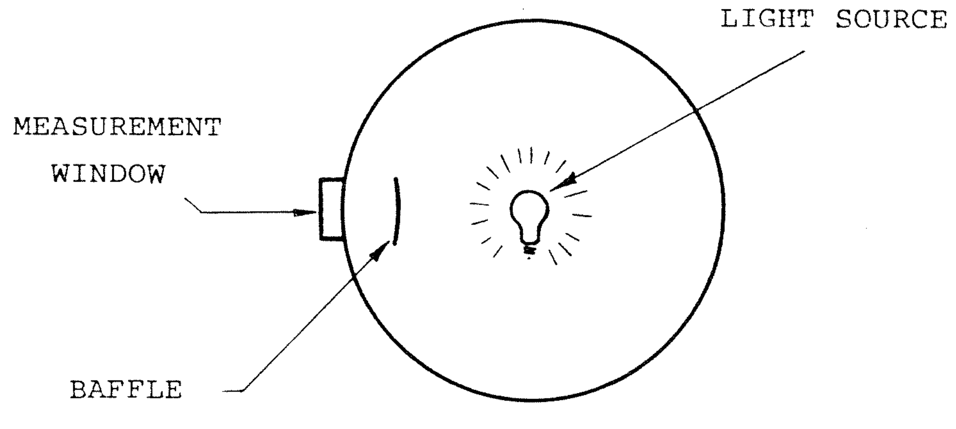

Figure No. 5 - Photometer Sphere

The receiver is placed on the outside of the sphere at the window. Both phototube and photocell types of receivers are used. These receivers pick up the light energy and convert it into

MEASUREMENT OF LIGHT - (CONTD.)

electrical energy. This is either measured by a galvanometer or put through an amplifier and digital volt meter. If the former, the resultive signal must be manually multiplied by a calibration constant to convert to Lumen values. If the latter, the multiplication can be done automatically. Calibration constants are determined for each sphere by photometry and standard lamps of known luminous flux. The characteristics of the receiver and filters must be such that when combined with the sphere paint characteristics, they will produce a spectral response that duplicates the visibility curve, as closely as possible. Since the output of a lamp depends largely upon the voltage impressed upon it, the power supply, voltage regulation and electrical measuring instruments become important factors in obtaining accurate measurements.

It has been proved that the same Ampere and Lumen values will prevail for an incandescent lamp, whether they are measured on alternating or direct current. However, a direct current power supply is more easily regulated and it permits the use of D.C. instruments which have more desirable characteristics for this application.

All incandescent lamps pass through a period of rising Lumen values during the early part of life. This is caused by a realignment of the crystalline structure of the filament and a change of the surface conditions. (See Section 1.4).

MEASUREMENT OF LIGHT - (CONTD.)

Therefore, to get accurate readings of Lumen and current, it is necessary to first age the test lamp; that is, burn the lamp at a fixed voltage for a given time. This is commonly known as seasoning (see Section 1.4). All lamps show a depreciation in light output during their burning life due, in part, to the inside blackening of the bulb. Due to this, lamps are rated, not only for their initial readings, but also at 70% of their life. This reading is commonly called maintenance and it is a means of evaluating the quality of a lamp for Lumen performance over its life.

The most important step in all photometric work is to make sure the equipment is calibrated by standards which are traceable to the National Bureau of Standards. Reference lamps can be purchased from the U. S. National Bureau of Standards or established laboratories like ETL.

Large lamps (GLS) are measured in lumens and lumens per watt (lpw).

Miniature lamps are measured in Mean Spherical Candlepower MSCP.

To convert MSCP to lumens: $\text{MSCP} \times 4\pi = \text{Lumens}$, or

$$\frac{\text{MSCP} \times 4\pi}{\text{lamp wattage}} = \text{lpw}$$

1.2.1 IES APPROVED METHOD FOR ELECTRICAL AND PHOTOMETRIC MEASUREMENTS OF GENERAL SERVICE INCANDESCENT FILAMENT LAMPS

FOREWORD

This guide is one of a continuing series of IES Approved Methods being prepared to create a greater uniformity of photometric measurements and reporting among various laboratories. The material covered here was developed to provide a uniform method for photometric and electrical measurements for data now required on certain incandescent filament lamps.

INTRODUCTION

General. This guide describes the procedures and precautions to be observed in the photometry of general service incandescent filament lamps to obtain reliable measurements which can be duplicated in different laboratories performing the same task under substantially the same controlled conditions.

Scope. Incandescent filament lamps, as covered by the guide, produce radiation in the visible portion of the electromagnetic spectrum as a result of passing current through a tungsten filament, surrounded by an inert atmosphere or vacuum in a glass envelope. The measurements that are normally made in lamp photometry are luminous flux, intensity and electrical characteristics. In addition, luminance measurements are sometimes required.

Details not covered in this guide may be found in the "IES General Guide to Photometry,"[1] "IES Practical Guide to Photometry,"[2] "Photometry"[3] by J. W. T. Walsh, and other suitable references.[4-10]

1.2.1 INTRODUCTION -- Scope (Contd.)

Excluded from this guide are such types as reflector lamps which are covered in other guides.[7]

It is often important to know the life along with light output and electrical characteristics of incandescent filament lamps. For such information, refer to the "IES Approved Method for Life Testing of General Lighting Incandescent Lamps."[4]

This guide also describes electrical and photometric testing of incandescent filament lamps and how these tests are related to life test and lumen maintenance data:

(1) Electrical testing consists of measuring amperes and volts, with one or the other held constant, thereby allowing calculation of watts.

(2) Photometric testing consists of measuring the light output (flux or intensity) of individual lamps. Flux measurements allow calculation of efficacy.

(3) Life testing consists of operating lamps at controlled voltage or current and noting starting and failure times.

(4) Lumen maintenance data are obtained by photometry at certain operating time intervals (specified percentages of rated life).

NOMENCLATURE AND DEFINITIONS [8-10]

(1) Units of electrical measurement are volts, amperes, and watts.

(2) Units of photometric measurement are lumens (luminous flux), mean spherical candlepower (flux) or candlepower in a specified

NOMENCLATURE AND DEFINITIONS (CONTD.)

direction (intensity).

(3) Seasoning refers to the time required for operating of an incandescent filament lamp to obtain sufficient tungsten recrystallization for the electrical stability needed for photometric or electrical testing.

(4) Regulation refers to constancy of voltage or current applied to the lamp during test.

(5) Multiple lamps (those rated by wattage or voltage and operated directly across a supply line) are those normally tested at constant voltage, and series lamps (those rated by amperes and operated in series across a supply line) are those normally tested at constant current.

(6) Standard cell refers to an emf standard (normally unsaturated) used as a reference in conjunction with precision potentiometers, which in turn are used to measure dc voltage and current.

(7) Secondary lamp standards are lumen or candlepower standards derived from the primary national standard and are used to establish working standards, which in turn are used to calibrate photometers.

TEST CONDITIONS

General. The environment in which lamps are to be tested is most important to the reliability of test results.

Temperature. Temperature constancy is one of the most important environmental considerations. Most of the equipment used for

TEST CONDITIONS (CONTD.)

photometry and electrical tests will measure repeatably at any given temperature between +4°C and +40°C, but corrections to standard conditions may be required. If corrections are necessary they should be made in accordance with the instrument manufacturer's recommendations. To avoid making these corrections, standard temperature conditions should be 25° ± 1°C.

Vibration. Vibration may cause electrical lamp instability and instrument errors, and may cause premature lamp failure because of filament brittleness. Therefore, vibration should be kept to a minimum in the test equipment, and extreme care should be exercised in the handling of both unlighted and lighted lamps.

Extraneous Light. Extraneous light will affect all photometric measurements. To overcome this problem it is necessary in the case of lumen measurements to mount the lamp in an enclosure, such as an integrating sphere; or in the case of candela measurements, the lamp should be mounted in a dead (non-reflecting) enclosure, or in a completely flat-back room using baffles.

Power Supply. Type of power supply to be used depends upon the type of testing to be done, as follows:

(1) Series lamps require either a constant current source, or a constant voltage source, depending on individual requirements.

(2) Multiple lamps are normally tested on direct current at rated voltage. A dc supply with a regulation of 0.1 per cent or better and a ripple content not exceeding 0.4 per cent of the output voltage is required in this case.

TEST CONDITIONS (CONTD.) -- Power Supply

(3) It may be desirable or necessary to test multiple lamps on alternating current. The ac power supply should have a voltage wave shape such that the rms summation of the harmonic components will not exceed three per cent of the fundamental. If the static type of voltage stabilizer is used, it is of particular importance to check the wave shape. The line voltage should be as steady and as free from sudden change as possible. For best results the voltage should be regulated to within ± 0.1 per cent. If adequate automatic regulation is not available, constant checking and readjustment are essential if accurate measurements of lamp characteristics are to be obtained. Where the ac line regulated supply distorts the wave shape, it is necessary to use a thermocouple or dynamometer-type ac meter. In the latter case, the current drawn by the meter must be taken into account.

EQUIPMENT AND INSTRUMENTATION

Instruments. For selection and care of instruments used in electrical and photometric testing, see "IES Guide for the Selection, Care and Use of Electrical Instruments in the Photometric Laboratory."[5]

(1) The analog-type voltmeters, ammeters, and wattmeters used in testing should have an accuracy of at least 0.25 per cent of full scale deflection. All ac instruments must be compatible with the wave shape existing at the test location to indicate true rms values.

(2) Digital voltmeters and ammeters have advantages in accuracy, speed and direct read-out, eliminating many sources of error.

EQUIPMENT AND INSTRUMENTATION (CONTD.)--Instruments

(3) Recording instruments may be used to record the stability of a power supply and the candlepower distribution on a goniometer.

(4) Photoelectric detectors and instruments generally consist of a color-and cosine-corrected photovoltaic cell or a phototube. The detectors are connected to a null-balance instrument, an indicating microammeter, galvanometer, an operational amplifier, or digital readout devices. Because of the detector's temperature dependency it may be necessary to apply appropriate corrections to the readings obtained.

Photometric Equipment. There are three types of photometric equipment in general usage: the integrating sphere, the goniometer, and the bar photometer. For convenience, electrical measurements may be made on any of these photometers just prior to the reading of lumens or candelas.

(1) Luminous flux (lumens) or mean spherical candlepower, is determined with an integrating photometer. Care should be exercised in selecting an integrating photometer of suitable size for the physical size of the lamp being tested, since the ratio of the volume taken up by the lamp and lamp holder to the total volume of the sphere should be as small as possible. However, the sphere should be sufficiently small to obtain a minimum of two footcandles (2.2 dekalux) of incident light on the photovoltaic cell. The sphere should be properly painted inside and contain a baffle between the lamp and detector. If the lamp being measured is a different size or color temperature than the standard used to calibrate the

EQUIPMENT AND INSTRUMENTATION (CONTD.)--Photometric Equipment

sphere system, a color correcting filter should be used immediately in front of the detector.

(2) Candlepower distribution is determined with a goniometer. The goniometer provides means for changing the vertical and horizontal angular relationships between the photocell and the photometric center of the lamps. It must accurately indicate the photocell viewing angle while maintaining constant lamp to photocell distance. The photometric center of rotation of a clear glass lamp should be the center of the filament. The photometric center of a frosted glass lamp should be at about the center of the glass envelope.

(3) Candlepower (luminous intensity) is determined with a goniometer or bar photometer. The bar photometer provides a direct comparison between the test lamp and the working standard.

SELECTION OF TEST LAMPS

Test lamps should be representative of the lot from which taken. The value of the test will depend upon the method of sampling, size of sample, conditions of testing, and many other factors. The effects of such variables are discussed in "Experimental Statistics",[6] Handbook 91, issued by the National Bureau of Standards.

PRETEST PROCEDURES

Handling and Storage. The lamps should be handled, transported and stored in such a way as to minimize the effects of vibration and shock on the filaments.

PRETEST PROCEDURES (CONTD.)

The lamps should not be subjected to high humidity conditions as this could weaken the cement bond between base and bulb or cause corrosion of the metal base shell resulting in high resistance and inaccurate electrical measurements.

Storage should be in a relatively clean atmosphere so as to eliminate the effect of dirt on light output. It is necessary to clean lamps prior to and after photometry to eliminate handling marks.

Identification. Lamps should be marked for identification with numbers or letters around the neck of the bulb. Care should be taken to use marking ink (preferably black) that will not fade and will be heat resistant so that identification is not lost during the life test. Lamps used for horizontal candlepower measurements should be marked or etched to show which is the sensor side and the direction of calibration.

Lumen Maintenance Data. If lumen maintenance data are required, the life periods at which lamps are to be photometered should be determined. The most commonly accepted periods are after seasoning, at 35 per cent rated life and at 70 per cent rated life; however, other or additional points may be selected to meet the particular need.

Initial Photometry. Lamps which are to receive their initial photometry should be seasoned for at least 0.5 per cent of rated life at rated volts, or rated current, or correspondingly shorter times for higher than rated volts or current.

TEST PROCEDURES

Stabilization and Calibration of Equipment.

When a detector is used, the first and foremost precaution is to make certain that the detector(s) has been fatigued. Failure to do so will result in unreliable data.

The next step is to perform the necessary calibration procedures such that the reading of the detector response will be a true indication of light output. Working standards are normally used for this purpose. It is recommended that at least three working standards be used to calibrate the system, and the average of the values at the time of standardization compared to those at the time of calibration be used to determine a correction factor. Rechecking should be made with sufficient frequency to assure a constantly uniform calibration.

All equipment used for measurements must be stabilized according to the manufacturer's recommendations.

Observation, Recording, and Computation.

All pertinent data required on the test report (see Section 8) should be recorded as observed with any necessary corrections made and so indicated.

TEST REPORT

Test reports should include pertinent items of the following data:

(1) Date of test Report.

(2) Number of lamps tested and sampling procedures used.

(3) Description of lamps.

(4) Description of equipment.

(5) Description of standards used.

(6) Life, electrical and output rating of lamp.

(7) Intervals of measurements.

(8) Special test conditions -- operating position.

(9) Corrections applied.

(10) Computations made (watts if measured on dc).

(11) Candlepower distribution curve (if applicable).

(12) Actual electrical and output readings.

(13) Lumen maintenance and efficacy computations.

(14) Statistical analysis.

REFERENCES

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TESTING INCANDESCENT LAMPS

INCANDESCENT LAMP LIFE TESTING

1.3 Life tests of incandescent lamps are divided into 2 classes.

A. Rated voltage - normal testing

B. Over-voltage - forced life testing

For A, rated voltage tests, lamps are operated at rated voltage in a specified burning position on a life test rack. The voltage should be regulated to ± .25%.

For B, Over-voltage test, lamps are operated at a voltage above rated volts and normal life is calculated using lamp performance data as indicated in 1.000, Chapter I. Life testing is sometimes indicated as "factor 1", "factor 6" or "factor 200" tests.

Factor 1 is a life test at design or rated volts (also called normal testing).

Factor 6 is a force test at 115% of rated volts. Life is approximately one sixth of life at rated volts.

Factor 200 is a force test at 150% of rated volts. Life is approximately one two hundredth of life at rated volts.

1.3 Incandescent Lamp Life Testing

Life test data is used to compute rated life of incandescent lamps. In U. S., there are two ways of computing rated life.

I - Burn all lamps in a group until all have failed. Sum up total burning hours of all lamps and divide by number of lamps on test. This yields average life or rated life.

II - Burn all lamps in a group until the point is reached where 50% have failed and 50% are still burning. This point is called rated life.

In Europe and some South American countries, life test calculations are specified by the International Electrotechnical Commission (IES) Publications 64.

1.31 IES APPROVED METHOD FOR LIFE TESTING OF GENERAL LIGHTING INCANDESCENT FILAMENT LAMPS

Prepared by the Testing Procedures Committee
of the Illuminating Engineering Society

1. Introduction and Scope

The following describes procedures for life testing of incandescent filament lamps, including general lighting types used in home, office, industrial, institutional and commercial installations. Tungsten-halogen and streetlighting lamps are included; types not included are automotive, miniature and sub-miniature, photolamps and other special types. The procedures are designed to reduce the effect of conditions, extraneous to the lamp itself, such as burning position, voltage variation, vibration, etc.

Incandescent filament lamps produce radiation in the visible portion of the electromagnetic spectrum as a result of passing current through a tungsten filament, surrounded by an inert atmosphere or vacuum in a glass envelope. As long as the filament remains intact, current will flow, heating the wire to incandescence, and thus producing light.

Since incandescence requires high temperatures, the surface of the tungsten filament is continually being vaporized during lamp operation. As a result, the filament wire diameter is decreased until, at some point along its length, the cross section is too small to carry the current, causing the filament to burn out. The rate of evaporation is also dependent on filament temperature.

1. INTRODUCTION AND SCOPE - (CONTD.)

Life testing of incandescent filament lamps at rated voltage is described. Accelerated testing (testing at higher than rated voltages or current) is often used by lamp manufacturers for quick evaluation and comparative testing, but is not considered accurate for absolute evaluation of lamp life and is not considered here.

It is often important to know light output and efficacy along with the life of incandescent filament lamps. Also, lumen maintenance during life of a lamp is often desired. For information on photometry of incandescent filament lamps, see the "IES Practical Guide to Photometry,"[1] "IES General Guide to Photometric,"[2] and the "IES Approved Method for Electrical and Photometric Measurements of General Service Incandescent Filament Lamps."[3]

2. Nomenclature and Definitions

Units of electrical measurement used throughout this guide are volts, amperes, and watts.

Life of test lamps is expressed in hours and refers to actual burning time, not including any off time because of cycling.

Seasoning refers to the time required for operating an incandescent filament lamp until it is considered stable for photometric testing. Seasoning time is included in the test life of the lamp being reported.

Regulation refers to constancy of voltage or current applied to the lamp during test.

3. <u>Laboratory Requirements</u>

(1) The environment in which lamps are tested is most important to the reliability of the test results, as follows:

(a) Vibration is one of the most important factors to consider in life testing of incandescent filament lamps. As they burn, incandescent filaments become brittle. Undue shock or vibration can cause filament fracture before it has reached normal failure mechanism described in Section 1 above; therefore, test positions or racks should be mounted on pads or spring, or suspended from springs that will absorb shock and vibration.

(b) Temperature and humidity are less important environmental considerations, but circulation of air around the test lamp(s) should be sufficient to maintain temperatures of surrounding wiring, bus duct, conduit, etc., at a safe maximum.

(2) Life test racks should be of open design, i.e., only bare sockets should be used - no globes, or reflectors, unless specific environmental testing is required. However, this design requires guards, interlocks, etc. for operator safety reasons as outlined by OSHA, the National Electrical Code and the Canadian Electrical Code.

(3) Lamp holders (sockets) should be of the porcelain-type construction with sturdy threaded shells and center contacts to withstand continual insertion and removal of test lamps. Routine maintenance of test sockets includes cleaning of accumulated dirt and metal dust from base-down and horizontal-burning sockets, plus replacement of sockets which show signs of arcing on the shell or center contacts.

3. LABORATORY REQUIREMENTS (CONTD.)

Sockets with nickel plated threaded shells are preferred over plain brass or aluminum sockets. In order to obtain the greatest precision in test results as well as a relatively maintenance-free test facility, it is recommended that each bar of test positions be constructed from two copper bus bars. One of these must be machined to accept the shells of an incandescent base, and the other must serve as a common for the lamp center contact.

(4) When testing lamps in series circuits, such as street series lamps, "cutout" receptacles are required so that when one lamp fails, the remaining lamps in the circuit will continue to burn. Power supply for series lamps should be from a constant current source regulated to within 0.5 percent.

(5) Electrical conductors to the test rack and sockets should be of adequate size for handling the current load (National Electrical Code and Canadian Electrical Code Part 1) and for minimizing voltage drop throughout the system. Figure 1 (below) shows alternate feed wiring to individual bars which will minimize voltage drop at the bars. The entire system should be designed to limit this drop to a maximum of 0.1 percent, and under these conditions a voltmeter may be connected to any lamp to obtain a representative voltage measurement for that particular bar of lamps.

3. LABORATORY REQUIREMENTS (CONTD.)

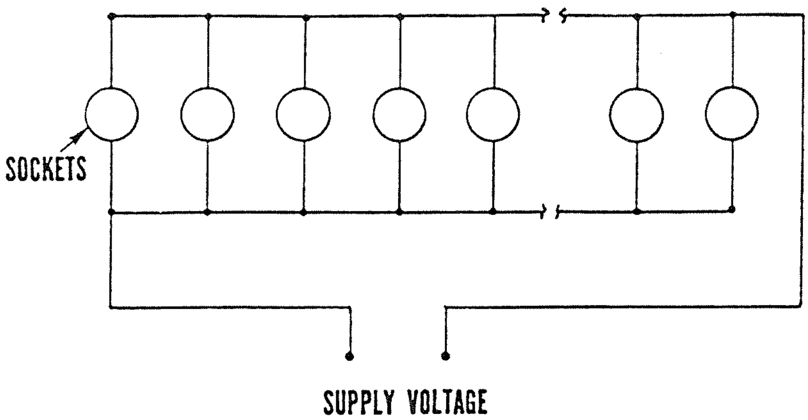


Figure 1. Alternate feed to minimize voltage drop.

(6) Regulated 60 Hz, ac power is generally used in life testing. The ac power supply should have a voltage waveshape such that the rms summation of the harmonic components does not exceed three percent of the fundamental. The line voltage should be as steady and free from sudden changes as possible. For best results, the voltage should be regulated to within 0.1 percent. If adequate automatic regulation is not available, frequent daily checking and readjustment are essential for obtaining a true measurement of lamp life.

(7) Lamps used in transportation service, on dc systems, may have different life characteristics when tested on dc power than when tested on ac power (due to crystal growth in microstructure, water cycle effects, etc.) It may, therefore, be appropriate to test such lamps with dc power, which shall be regulated to within 0.1 percent.

4. INSTRUMENTATION

For the selection and care of instruments, see the "IES Guide for the Selection, Care, and Use of Electrical Instruments in the Photometric Laboratory".[4]

In life testing, accurate recording of elapsed time is important. The elapsed time meter should be connected to the voltage supply so that it operates only when the rack is energized. Thus, in the event of a power failure to the rack, or during off cycles, the meter will also stop.

5. Selection of Test Lamps

Test lamps should be representative of the lot from which taken. The degree to which the test samples represent the group affects the value of the test results. Since life tests are performed only on a small portion of the total product, the obtained results will serve as an indication of the average performance of the entire lot. The value of the test will depend on the method of sampling, size of sample, conditions of testing, and many other factors. The effects of such variables are discussed in Chapter 1 of Experimental Statistics - Handbook 91[5] issued by the National Bureau of Standards.

6. Pretest Procedure

Lamps should be marked for identification with numbers or letters around the neck of the bulb. Care should be taken to use marking ink that will not fade, and will be heat resistant so that identification is not lost during the life test.

Lamps which are to be photometered should be seasoned and handled in accordance with the "IES Approved Method for Electrical

6. PRETEST PROCEDURE (CONTD.)

and Photometric Measurements of General Service Incandescent Filament Lamps."[3] Any lamp failures that occur on seasoning should be recorded as initial failures and reported as such in the life test data.

7. Life Testing

Most life testing of incandescent filament lamps is done with lamps burning in an intended end use (base-up, base-down, etc.) position. Many positions may be used, but testing of similar lots and/or consecutive lots should all be in the same position so as to be consistent. Double ended tungsten-halogen lamps should be tested within four degrees of horizontal or as given in notices supplied with the lamps. Also, the test report should describe burning position.

When lamps are removed for photometry during the life test, it is recommended that a silicone lubricant by applied to lamp bases before starting the test. This prevents vibration and "chattering" when removing the lamp from the socket. Such vibrations could cause the filament to break prematurely.

It is recommended that normal life test lamps be turned off for ½ hour each day or long enough to permit lamp and sockets to return to room temperature. This or any other burning cycle which might be chosen should be included in the test report.

If lamps are removed for photometry at several periods within the life of the lamp, extreme care must be used in handling lighted

7. LIFE TESTING (CONTD.)

and unlighted lamps, especially toward the end of life as the filament becomes brittle.

8. Detection of Failures

Life test failures may be recorded by visual observation of life test racks. Lamps should be monitored at intervals that represent no more than ½ percent of their rated life. If greater accuracy is required, evaluation should be changed accordingly.

Automatic recording of failures may be accomplished through the use of photoelectric cells or thermocouple devices connected to elapsed time meters. Also, a camera may be employed to automatically photograph entire sections of life test racks, with a clock in the picture to record time of observation.

A valuable part of any life test operation is the analysis of the lamps at failure. Such analyses should determine the cause of failure (where feasible) especially if the failure time is abnormal.

9. Reporting of Test Results

Lamps should be clearly identified as to rating, sampling procedure, source of test lamps, and all appropriate dates.

Test procedure should be clearly described giving burning position, burning cycle, test voltage (also designate ac or dc), and any other data necessary to completely describe the test. Photometric data also may be reported with life test data.

9. REPORTING OF TEST RESULTS (CONTD.)

Statistical analyses of test data are essential considerations. Such things as average, range, standard deviations, are valuable measurements to be considered and should be included where possible.

References

1. Committee on Testing Procedures of the IES, "IES practical guide to photometry," Journal of the Illuminating Engineering Society, Vol. 1, No. 1, October 1971, p. 73.

2. Committee on Testing Procedures of the IES, "IES general guide to photometry," Illuminating Engineering, Vol. 50, No. 3, March, 1955, p. 147; and No. 4, April 1955, p.201.

3. Committee on Testing Procedures of the IES, "IES approved method for electrical and photometric measurements of General service incandescent filament lamps," Journal of the Illuminating Engineering Society, Vol. 3, No. 2, January 1974, p. 163.

4. Committee on Testing Procedures of the IES "IES guide for the selection, care and use of electrical instruments in the photometric laboratory," Illuminating Engineering, Vol. 63, No. 7, July, 1968, p. 376.

5. Experimental Statistics - Handbook 91, National Bureau of Standards, U.S. Government Printing Office, Washington, D.C., August 1963, Chapter 1.

6. W. R. Purcell, "Saving time in testing life of incandescent lamps," Transaction of the American Institute of Electrical Engineers, AIEE Proceedings, Vol. 68, Part 1, 1949, p. 730.

REFERENCES (CONTD.)

7. G.W. Middlekauff, B. Mulligan, and J.F. Skogland, "Life testing of incandescent lamps at the Bureau of Standards, "U. S. Bureau of Standards, Science Paper 265, March 16, 1916, 25 pp.

INCANDESCENT LAMP LIFE TESTING (CONTD.)

A useful calculation to compare life test data with catalogue specifications is LPW/dl or lpw at design life. The calculation uses exponent b from Table II, Section 1.1.

$$\text{LPW/dl} = \left[\frac{\text{Actual Life}}{\text{Design Life}}\right]^{\frac{1}{b}} \times \text{Actual LPW}$$

OVERNIGHT AGE AND ROTARY BUMP TEST OR OARB

The OARB test is a measure of the ability of the coil and mount to withstand cold shock and vibration. The lamps are lifted and dropped by the rotary motion of a notched drum. A special piece of equipment known as the Michigan Rotary Drum Tester is required. Lamp failure is checked by a continuity meter. See GTE Sylvania specification #2E0602-1C.

VARIABLE DROP TEST

The variable drop test is run with the lamp unlighted. The lamps are dropped from heights of 9, 16, 25, 36, and 49 inches respectively. The lamps are dropped once from each height until failure. Failure is checked by a continuity meter. See GTE Sylvania Specification #2E0602-11D.

VIBRATION TEST

This test is for rough service lamps and vibration service lamps. Test lamps are not seasoned. Lamps are burned at rated volts. The frequency of vibration is 28.5 - 30.5 vibrations per second. The amplitude is 10-13 vibrometer scale units.

See GTE Sylvania Specification #2E0602-2E.

VIBRATION AND PENDULUM BUMP TEST

This test is a vibration and cold shock test performed on appliance lamps. The equipment consists of a rack suspended on springs to isolate it from external vibrations. The rack is bumped by a molded-rubber socket suspended in pendulum fashion on a light chain 54 inches from point of suspension. Lamps are alternately bumped and vibrated until failure.

See GTE Sylvania Specification #2E0602-15B.

HOT SHOCK TEST

This test covers rough service lamps tested to meet Naval Shipboard use specifications.

See GTE Sylvania Specifications #2E0602-3B.

PUFF TEST FOR DETECTION OF OXYGEN

Lamps are run at low voltage for a short time and then examined for oxidized coils or a puff of smoke (tungsten oxide evaporation) when lamp is brought up to rated voltage.

See GTE Sylvania Specifications #2E0602-13.

TORQUE TEST FOR LAMP BASES

This test is to check absence of basing cement, uncured cement, over-cured cement or improperly mixed basing cement. The lamps are

TORQUE TEST FOR LAMP BASES - (CONTD.)

are tested by applying a torque to the base. The minimum torque the base must withstand before breaking loose from the bulb is specified. See GTE Sylvania Specification #2E0404-711-712A and Specification #2E0300-6. (Refer to 7.4.36 and 7.4.6).

CYANOGEN TEST

The cyanogen test is a method of detecting the presence of oxygen as a contaminant in sealed and exhausted gas-filled lamps. The principle of operation is that very small amounts of oxygen will suppress the radiation from a cyanogen radical (CN) molecular system. Accordingly, in a transparent sealed envelope such as an incandescent lamp, containing a source of cyanogen, an accurate indication of the amount of oxygen present can be obtained by exciting the atmosphere in the bulb by high frequency radiation (a Teslar coil) and measuring the intensity of radiation of the cyanogen radical molecules. Cyanogen is normally formed by reaction between carbon in the filament and nitrogen in the fill gas. It is destroyed by collision with molecular oxygen, forming CO and NO. Thus the ratio of the intensity of CN molecular emission to N_2 molecular emission provides a measure of the concentration of molecular oxygen in the lamp atmosphere. Thereby, lamps can be rejected which are indicated to have excess oxygen as compared to a measurement or signal of a known reference lamp.

BASE ELECTRICAL TEST

For safety and convenience the lamp leads are soldered to the cap, which, for normal lamps - is either:

an Edison cap (base) i.e. a screw cap, or
a Swan cap, i.e. a bayonet cap.

BASE ELECTRICAL TEST (CONTD.)

In the Edison cap there is one centre contact and the cap shell serves as a second contact, in the Swan cap there are two end contacts and the cap shell is dead.

In the Edison cap the centre contact is connected to 120 or 220 volts and the cap shell is connected to the neutral line = earth (ground) this being a requirement for the installation. In the Swan cap one contact is connected to 220 volts and the other to earth (Ground).

The contacts (i.e. centre contact and shell of Edison cap, or the two contacts of Swan caps) must be separated by a very good insulator. The insulator is usually glass which has a high insulation resistance.

If a Swan contact or the centre contact of the Edison cap is not insulated adequately from the cap shell, the insertion of a new lamp may be very dangerous: If the shell is touched during its insertion into a live holder, one will get an electric shock. Frequently the electrician is standing on a ladder and this increases the risk.

The circuit tester (megger) would reject these lamps because it would register too low a resistance. B.S.I. specifications demand a minimum of 50 megohms between contacts and shell under specific (dry) conditions. A Swan cap is safer than an Edison cap because the Swan cap shell is never alive. Swan caps are used in the United Kingdom and all English speaking countries except in U.S.A. and predominantly in France. The Edison base is standard in the United States, Canada and several South American Countries.

STANDARD METHOD FOR DESIGNATING NATURE AND POSITION OF FAILURE OF TEST LAMPS

Most failures of lamps are of the burnout or arc variety with an occasional failure due to handling.

DESCRIPTION OF FAILURE	DESIGNATION
Burn Out	BO
Arc Fuse Burned Out	Arc PG
Two-lead arc, chipped or cracked press	Arc CP
Cold Bump	CB
Rotary Bump	RB
Lead Broken	LB
Broken Filament	BF
Broken Filament due to handling	BFH
Turn-on Failure	TO

See GTE Sylvania Specification #2E0601-4A

See Chapter 15 - Section - Defect and Shrinkage Symbols

FLASHING

1.4 Flashing is the term used to describe the initial lighting of an incandescent lamp. The purpose of the flashing process is to clean the coil surface, and to recrystallize the tungsten into the proper high temperature interlocking structure needed for resistance to sag during its burning life. Usually it is the last step in the manufacturing process. Engineering specifications spell out the particular manner in which flashing is to be done for each lamp type. The procedure specified is called a flashing schedule. In some respects the flashing schedule varies considerably from one lamp to another. In general, it consists of the lamp being lit up on six stations on the finishing machine for roughly two seconds each time.

Initially, because of surface impurities on the coil volatilized into the gas at first heating, an incandescent lamp acts like a gaseous discharge lamp. When voltage is applied, the atmosphere in the lamp ionizes and becomes conductive. The current passing through the ionized atmosphere causes an arc. This arc tends to draw a very high current and becomes destructive unless it is limited by a resistor in the circuit. Consequently, the flashing schedule will normally specify the resistor and open circuit voltage to be used at each station. The final position has no ballast or series transistor, since by that time all volatile impurities have been removed from the coil.

VACUUM LAMPS

Vacuum lamps are pumped down to a pressure of approximately 30 microns. To complete the job of evacuating the lamp, a getter is used. The tungsten coil is coated with a phosphorous getter. During flashing, while the gaseous discharge arc is taking place, the getter evaporates and combines with the residual gas molecules. This forms a solid which deposits on the bulb wall. A momentary bluish glow becomes visible while ionization occurs. As the clean-up takes place, the glow will disappear, indicating no further presence of gas.

FLASHING

GAS-FILLED LAMPS

Gas-filled lamps are filled with a mixture of high purity argon and high purity nitrogen. Usually the mixture is mostly argon. For example, the 60 watt GLS lamp contains about 94% argon, 6% nitrogen. Pure argon tends to ionize easily, promoting arcing. The addition of a small amount of nitrogen reduces the arcing tendency. The amount of nitrogen necessary to inhibit arcing depends on the lamp type. In general coiled coil types require more nitrogen than single coil types. Since nitrogen has a greater cooling effect on the filament than argon, it is desirable to use the least amount possible as long as arcing is avoided. The higher the argon ratio, the more efficient the lamp is in terms of lumens per watt for a given life rating. For this reason, lamps are produced close to the arcing threshold. Many gas-filled lamps, if not flashed according to the specified schedule, will arc when lit at rated volts. This is because of slight impurities present in the lamp atmosphere or coming off the coil. In such cases it is necessary to provide a ballast to limit the current for the first few seconds while a clean-up takes place.

In addition to the clean-up, another important result is obtained by flashing. An unflashed coil can be stretched out to straight wire, while a flashed coil is very brittle and will break if stretched. This is due to the change in crystal formation which takes place as the coil reaches a very high temperature, usually at approximately the lamp's rated voltage.

GAS-FILLED LAMPS (CONTD.)

Flashing at too high voltage causes the coil to become very brittle, so that broken filaments occur in the normal handling that the lamps get in shipment. On the other hand, flashing too low results in sagging filaments. In a vertical filament lamp, sagging at flashing may cause close secondary turns in the lower part of the coil, which greatly shortens the life of the lamp. As a compromise, a flashing voltage is selected which keeps the filament ruggedness score just above the minimum acceptable, being sure that the amount of sag is not excessive.

In general, the problem of sag is confined to the initial droop occurring at flashing. Once the lamp is lit at rated volts, the filament takes a "set" and will exhibit no further tendency to sag. In some cases, such as in the infra-red types a very high flash is necessary to set the filament. This is because in service the filament operates at a temperature below that required to set it.

In general, fine wires or low current lamps develop better mechanical properties if initial heating is slow; conversely, high current heavy wire lamps need a fast heat rise. Capacitor discharge flashing is used for some high current lamps. Contaminated or improperly cleaned filaments are a major cause of arcing during flashing. Delayed arcs are often caused by contaminated moly support wires since it takes a few seconds to heat the support wire sufficiently for clean-up after the lamp is energized.

AGEING OR SEASONING

1.5 When standard incandescent lamps containing tungsten filaments are lighted for the first time, at constant, rated voltage, there is a rapid increase in luminous output accompanied by a corresponding rapid decrease in current. Most of the change occurs within the first twenty minutes, but changes at a slower rate may continue for several hours. Typical changes during the first ten hours of burning of 100 watt A19 lamps of current manufacture show an increase of about 30% in luminous out-put and a decrease of 5 percent in lamp current and wattage.

For precise photometric work, lamps which are employed as standards must be first stabilized to avoid the effects of these early changes. The initial burning of the lamps is referred to as "seasoning".

The cause of the changes in lamps characteristic during the seasoning period (about 1% of rated life) is due to recrystallization of tungsten, smoothing of the wire surface and evaporation of contaminants and deposits from the wire.

Seasoning can be accelerated within limits by force seasoning by the same over-voltages as force or accelerated life testing (See section 1.3)

Lamps made with clean wire become seasoned quicker and with less change from initial values than lamps made from contaminated wire or black wire which has not cleaned sufficiently.

1.5.1 IES GUIDE TO LAMP SEASONING

Most of the current IES measurement guides [1-3] are vague when discussing the seasoning of lamps to be used in photometric, colorimetric, and electrical tests. The Testing Procedures Committee has prepared this report to provide the needed, more specific guidance on lamp seasoning, including forced seasoning to reduce testing time for certain lamps.

INTRODUCTION

OBJECTIVE. This approved method provides a guide that will promote uniform seasoning of lamps intended to be used for measurement of photometric, colorimetric, or electrical characteristics. Lamps should be seasoned until those characteristics remain constant during the test to be conducted.

SCOPE. This approved method will apply to incandescent, fluorescent, high intensity discharge (HID) and glow lamps. The seasoning schedule for a new type lamp should be similar to a listed type with which it most closely agrees.

SUGGESTED SEASONING SCHEDULE

INCANDESCENT LAMPS. This category will consist of most filament lamps having self-emission of radiant energy in the visible spectrum due to thermal excitation. It will include both gas filled and vacuum lamps. It will serve to indicate forced seasoning required for photometry when time does not permit the recommended burning of one-half to one percent of rated life at rated volts. It is preferable to overseason a lamp rather than to underseason it.

INCANDESCENT LAMPS (CONTD.)

On range voltage lamps, use center voltage for calculation. Unless otherwise specified, lamps should be seasoned in their base up position.

GENERAL LIGHTING SERVICE. To include lamps of 100 to 135 volt circuit voltage having a wattage up to 1500.

(1) 0 to 999 rated hours, season 45 minutes at 115 percent of rated volts.

(2) 1000 rated hours and over, season at 120 percent of rated volts for one-half hour per each 1000 hours of design life or portion thereof.

EXTENDED SERVICE LAMPS. Same as general lighting service.

ROUGH SERVICE OR VIBRATION SERVICE LAMPS.

Season 45 minutes at 115 percent of rated volts.

SILVERED BOWL LAMPS. Same as general lighting service lamps.

THREE-LIGHT LAMPS. Season at 115 percent of rated volts for 60 minutes with both filaments burning.

TUNGSTEN-HALOGEN LAMPS.

Season one percent of rated life at rated volts.

MINIATURE-SUBMINIATURE LAMPS.

(1) Flashlight.

Less than ten hours rated life, season five minutes at 100 percent of rated volts.

11 to 29 hours, season ten minutes at 100 percent of rated life.

MINIATURE-SUBMINIATURE LAMPS (CONTD.)

(1) Flashlight.

30 to 59 hours, season 25 minutes at 100 percent of rated life.

76 to 100 hours, season 30 minutes at 110 percent of rated life.

101 to 150 hours, season 30 minutes at 115 percent of rated life.

(2) Aircraft Lamps. Season 28-volt lamps 20 minutes at 115 percent of rated volts.

(3) Automotive Lamps. Season at design volts for 20 minutes.

MULTIPLE STREET LAMPS. Same as general lighting service lamps.

SERIES STREET LAMPS. Season at 110 percent of rated current for four hours. Make frequent checks of current setting to correct drift.

TRAFFIC SIGNAL LAMPS. Season at 115 percent of rated volts for one hour.

HIGH VOLTAGE LAMPS (200 to 300 volts)

(1) Less than 200 watts, season 45 minutes at 115 percent of rated volts.

(2) More than 200 watts, season 90 minutes at 115 percent of rated volts.

AIRCRAFT LAMPS (100-125 volts)

Same as general lighting service lamps.

MINIATURE-SUBMINIATURE LAMPS (CONTD.)

SHOWCASE LAMPS. Same as general lighting service lamps.

BIPOST AND PREFOCUS LAMPS (EXCEPT PHOTOGRAPHIC).

Same as general lighting service lamps.

AIRPORT AND AIRWAY LAMPS (EXCEPT HALOGEN)

(1) Season current type lamps at 110 percent of rated current for one hour per 1000 hours of rated life or portion thereof.

(2) Season voltage type lamps same as general lighting service lamps.

REFLECTOR LAMPS (SPOT, FLOOD AND GENERAL)

Season at 115 percent of rated volts for one hour for each 1000 hours of rated life or portion thereof over 1000 hours.

PAR LAMPS. Same as reflector.

PHOTOFLOOD LAMPS. Season five minutes at rated volts.

PHOTOGRAPHIC LAMPS (EXCEPT HALOGEN)

(1) T-BULB LAMPS

10 hour lamp, season 6 minutes at rated volts.

15 hour lamp, season 10 minutes at rated volts.

25 hour lamp, season 15 minutes at rated volts.

50 hour lamp, season 10 minutes at 110 percent of rated volts.

200 hour lamp, season 20 minutes at 115 percent of rated volts.

PHOTOGRAPHIC LAMPS (EXCEPT HALOGEN) -- (CONTD.)

(1) T-BULB LAMPS

300 hour lamp, season 30 minutes at 115 percent of rated volts.

500 hour lamp, season 45 minutes at 115 percent of rated volts.

(2) INTERNAL REFLECTOR LAMPS

75 hour lamp, season 30 minutes at 108 percent of rated volts.

500 hour lamp, season 2 hours at 108 percent of rated volts.

1000 hour lamp, season 4 hours at 108 percent of rated volts.

FLUORESCENT LAMPS. A fluorescent lamp is a low pressure mercury electric-discharge lamp in which a fluorescent coating (phosphor) transforms some of the ultraviolet energy generated by the discharge into visible light. No satisfactory method has been devised by which a fluorescent lamp may be force-seasoned. Season in a horizontal position at a 3-hour on, 20-minute off cycle. The hot pin must be identified for both seasoning and photometry to prevent variations. Both hot and cold cathode lamps must be operated on a suitable ballast which complies with the ANSI specification for 100 hours at rated line volts prior to making any measurements. High current-density lamps such as the 1500-milliampere lamps may require special techniques even after 100 hours to maintain stability.

HIGH INTENSITY DISCHARGE (HID) LAMPS. HID lamps are a general group of lamps consisting of mercury, metal halide, metal vapor and sodium lamps. All lamps in this group must be seasoned for 100 hours using the recommended ANSI specified auxiliary ballast, operating at rated line volts. Lamps should be seasoned in the same position in which they are to be tested. The higher potential leg should go to the same eyelet contact in the socket for seasoning and testing.

ULTRAVIOLET LAMPS. Season UV (ultraviolet) lamps in accordance with the recommendations of the manufacturer.

XENON LAMPS (SHORT ARC). Season a short arc xenon lamp as specified by the lamp manufacturer.

REPROGRAPHIC LAMPS. Season the same as HID sources.

GLOW LAMPS. In general, this is a group of neon or LED (light emitting diode) type lamps. They should be seasoned in accordance with the recommendations of the manufacturer.

REFERENCES

1. Testing Procedures Committee of the IES, "IES approved method for electrical and photometric measurements of general service incandescent filament lamps," IES LM-45, JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY, Vol. 3, No. 2, January 1974, p. 163.

REFERENCES (CONTD.)

2. Testing Procedures Committee of the IES, "IES approved method for life testing of high-indensity discharge lamps," IES LM-47, JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY, Vol. 4, No. 1, October 1974, p. 66.

3. Testing Procedures Committee of the IES, "IES approved method for photometric measurements of high-intensity discharge lamps," IES LM-51, JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY, Vol. 4, No. 3, April 1975, p. 229.

INRUSH CURRENT

1.6 Resistance of a cold filament is lower (1/12 to 1/18) than when it is hot. Consequently, the initial current, called "inrush" current, drawn by a lamp is a higher than normal operating current.

Maximum theoretical inrush current can be calculated by dividing peak voltage (approximately 170 volts for a 120-volt system) by cold resistance.

Inrush current is maximum at the first peak of the applied AC voltage. If the initial instantaneous applied voltage is at the peak, time to reach peak inrush current is zero. But, if the initial instantaneous voltage is decreasing, time to reach peak inrush current could be as much as 0.006 seconds.

Lamp Wattage	Normal Current (Amperes) 120-Volt Circuit	Maximum Inrush Current (Amperes)	Ratio, hot resistance to cold resistance	Time for current to reach normal value (seconds)
75	0.625	13.0	14.7	0.09
100	0.83	17.9	14.7	0.10
200	1.67	37.0	15.6	0.13
300	2.50	53.0	15.0	0.13
500	4.17	89.5	15.2	0.15
750	6.25	131.0	14.8	0.17
1000	8.3	195.0	16.5	0.18
5000	41.7	1060.0	18.0	0.32

1.7 COLOR TEMPERATURE

Designers often find it useful to know the apparent color temperature of an incandescent light source, especially in photographic lighting applications. Color temperature is the temperature at which a black body must be operated to have a chromaticity equal to that of the light source. The curve below expresses the approximate relationship between color temperature and luminous efficacy for a fairly wide range of wattages of gas-filled lamps. Lamp efficiency is frequently published, or it may be calculated from published lumens and wattage. From this value, it is possible to estimate the average color temperature of the filament.

There are actually three temperatures of interest in incandescent lamp engineering:

(Ts)	Black Body Temperature	^oK
(Tw)	True Temperature	^oK
(Tc)	Color Temperature	^oK

1.7 COLOR TEMPERATURE - (CONTD.)

Table III shows the relationship between the Ts, Tw and Tc for a range of temperatures.

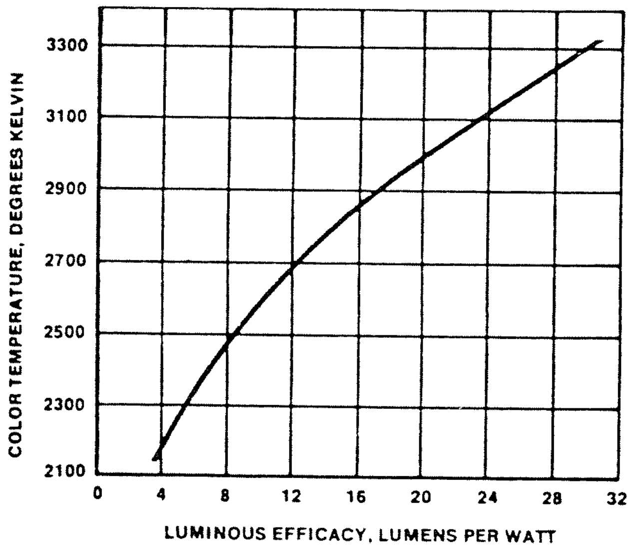
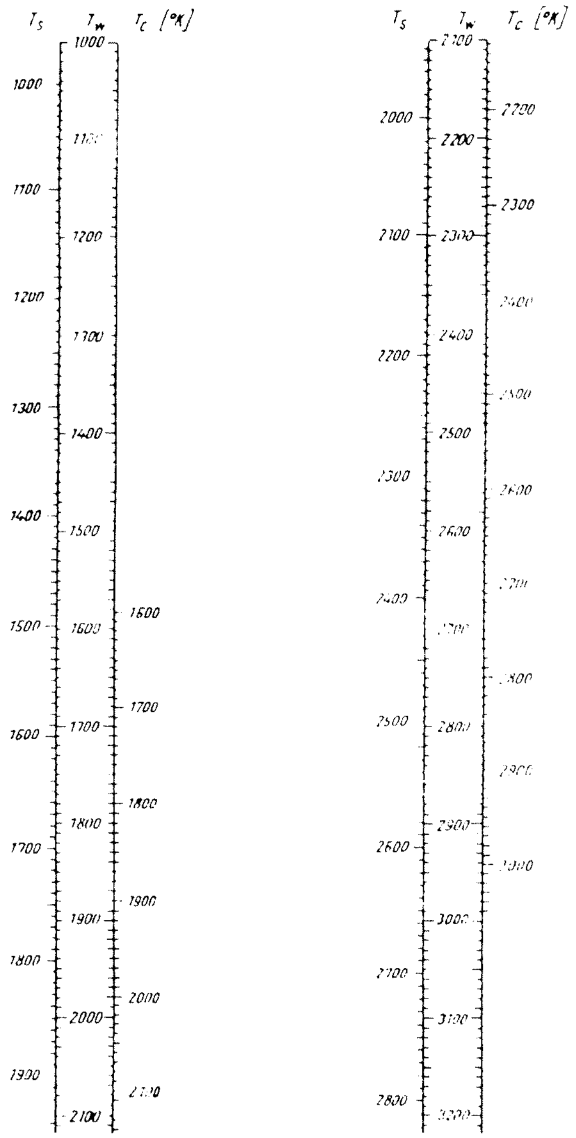


TABLE III



The three temperatures are not equal because (a) the radiant emittance of tungsten is less than unity, and (b) because it varies with wave length, being highest in the blue, and decreasing toward the infra red.

APPROXIMATE CALCULATIONS

Convert Lumens per watt to Color Temperature

$$Lpw^{.2326} \times 1479 = \text{Color Temperature } ^{\circ}K$$

Convert Lumens per watt to True Temperature

$$Lpw^{.21} \times 1486 = \text{True Temperature } ^{\circ}K$$

(Lpw 11 to 24)

$$Lpw^{.15} \times 1703 = \text{True Temperature } ^{\circ}K$$

(Lpw 2-11)

Convert Brightness $^{\circ}C$ to Lumens per watt

$$\text{Brightness } ^{\circ}C^{4.6688} \times 4.5624^{-15} = \text{lpw}$$

Convert Brightness $^{\circ}C$ to True Temperature $^{\circ}K$

$$\text{Brightness } ^{\circ}C \times 1.2528 = \text{True Temperature } ^{\circ}K$$

TABLE VII SHOWS THE COLOR TEMPERATURES AND LAMP DATA FOR COMMON GLS LAMPS

TABLE VIII

FILAMENT TEMPERATURES AND EFFICACIES OF 120 VOLT INCANDESCENT LAMPS

LAMP WATTS	BULB SIZE	APPROX. FILAMENT TEMP. °F	FILAMENT	APPROX. COLOR TEMP. °KELVIN	APPROX. INITIAL LUMENS	EFFICACY LUMENS PER WATT
6*	S-14	3860	C-9	2370	40	6.7
10*	S-14	3900	C-9	2450	81	8.1
25*	A-19	4190	C-9	2550	266	10.6
40	A-19	4470	C-9	2770	470	11.8
60	A-19	4530	CC-6	2800	855	14.3
100	A-19	4670	CC-8	2870	1720	17.2
150	A-21	4710	CC-8	2900	2760	18.3
200	A-23	4760	CC-8	2930	3800	19.0
300	PS-30	4830	C-9	2940	6000	20.0
500	PS-35	4840	CC-8	2960	10250	20.5
1000	PS-52	4980	CC-8	3030	23300	23.3
1500	PS-52	5010	C-7A	3070	33000	22.0

* Vacuum

CHANGE OF COLOR TEMPERATURE WITH LINE VOLTAGE

Not only is the color temperature higher for lamps of greater efficacy, but for any particular lamp the color temperature increases with line voltage. This is shown in Figure 3 for a 200 watt A-23 lamp.

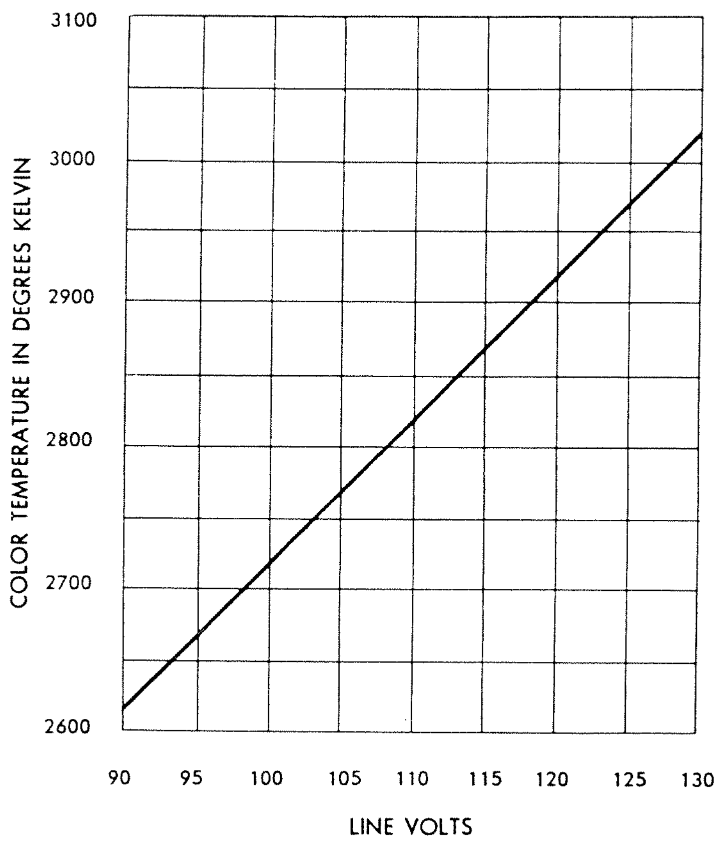


Fig. 3
Change of Color Temperature with Line Voltage for 200 Watt, A-23, 120 Volt Lamp

CLASSES OF LAMPS

1.8 Incandescent filament lamps are divided into three major groups: large lamps, miniature lamps, and photographic lamps. These are cataloged separately by lamp manufacturers. There is no sharp dividing line between the groups. The large lamp classification generally refers to those with larger bulbs, with medium or mogul bases, and for operation in circuits of 30 volts or higher. The miniature classification generally includes lamps referred to as automotive, aircraft, flashlight, Christmas tree, radio panel, telephone switchboard, bicycle, toy train, and many other small lamps generally operated from circuits of less than 50 volts. The photographic classification includes lamps designed for photographic or projection service. The following gives a brief description of a few of the many types of lamps that are regularly manufactured.

GENERAL SERVICE

These are large lamps made for general lighting use on 120-or 240-volt circuits. General service lamps are made in sizes from 15 watts to 1500 watts and satisfy the majority of lighting applications. The larger sizes are made in both clear and frosted bulbs, below 150 watts inside frosted bulbs are standard.

HIGH VOLTAGE (220-300 VOLTS)*

This voltage class refers to lamps designed to operate directly on circuits of 220 to 300 volts and represents a very small portion of the lamp demand in U.S.A. but is standard in Europe. Higher voltage lamps have filaments of smaller diameter and longer length and the filaments require more supports than corresponding 120-volt

HIGH VOLTAGE (220-300 VOLTS)* - (CONTD.)

lamps. They are, therefore, less rugged and produce 25 to 30 per cent fewer lumens per watt because of greater heat losses. The higher operating voltage causes these lamps to take less current for the same watts.

* It should be noted that lampholders should be Underwriter's Laboratories or Canadian Standards Association "approved" for voltage level appropriate to the voltage rating of the lamps being used, i.e. 250 volts for lamps up to 250 volts, 600 volts for lamps above 250 volts.

EXTENDED SERVICE

Extended service lamps are intended for use in applications where a lamp failure causes great inconvenience, a nuisance, or a hazard, or where replacement labor cost is high or power cost unusually low. These lamps have a reduction of approximately 15 per cent in light output. Extended service lamps with 2500 hours rated life are available. Where replacement of burned-out lamps is an easy, convenient operation, as in residential use, long life lamps are not usually recommended. For most general use, incandescent lamps with the usual 750 or 1000 hours design life give a lower cost of light than extended service lamps.

TRAIN AND LOCOMOTIVE

Lamps designated as train and locomotive service are designed for several classes of low-voltage (30, 60, 75, etc.) service, usually provided by generators, with a battery floated across the

TRAIN AND LOCOMOTIVE - (CONTD.)

line. Low-voltage lamps have shorter and heavier filaments than 120-volt or 240-volt lamp of the same wattage and, consequently, are more rugged and generally produce more lumens per watt, since they can be operated at higher temperature for a given life.

DC SERIES

Transit system voltages and some railway shop and yard voltages range from 525 to 625 volts. Lamps for this service on these voltages are operated five to twenty in series. The design voltages of individual lamps operated five in series are nominally 115, 120, and 125 volts. To identify DC series lamps, they are rated in odd wattages (36, 56, 94, 101, etc.)

Thirty-volt gas-filled lamps are also used for car lighting. The trolled voltage divided by 30 determines the number of lamps connected in series across the line. These lamps are equipped with short-circuiting cut-out which short-circuit the lamps on burnout, thus preventing arcing and leaving the remainder of the lamps in a given circuit operating. These 30-volt lamps are rated in amperes, instead of the usual watt rating.

SPOTLIGHT AND FLOODLIGHT

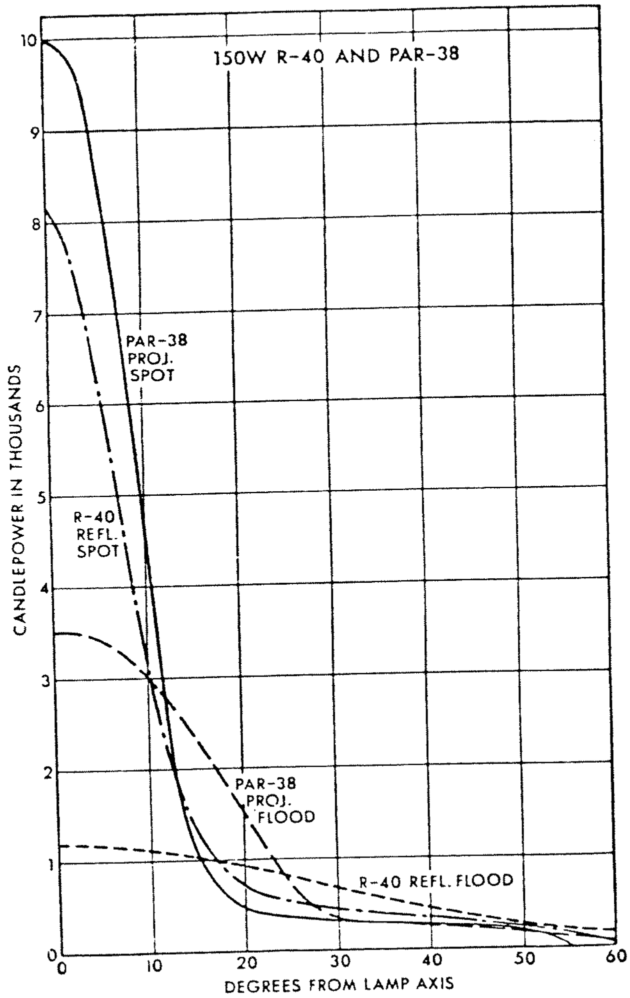
Lamps used in spotlights, floodlights, and other specialized luminaires for lighting theater stages, motion picture studios, and television studios have concentrated filaments accurately positioned with respect to the base. When the filament is placed at the focal point of a reflector or lens system, a precisely controlled beam is obtained. These lamps are intended for use with external reflector

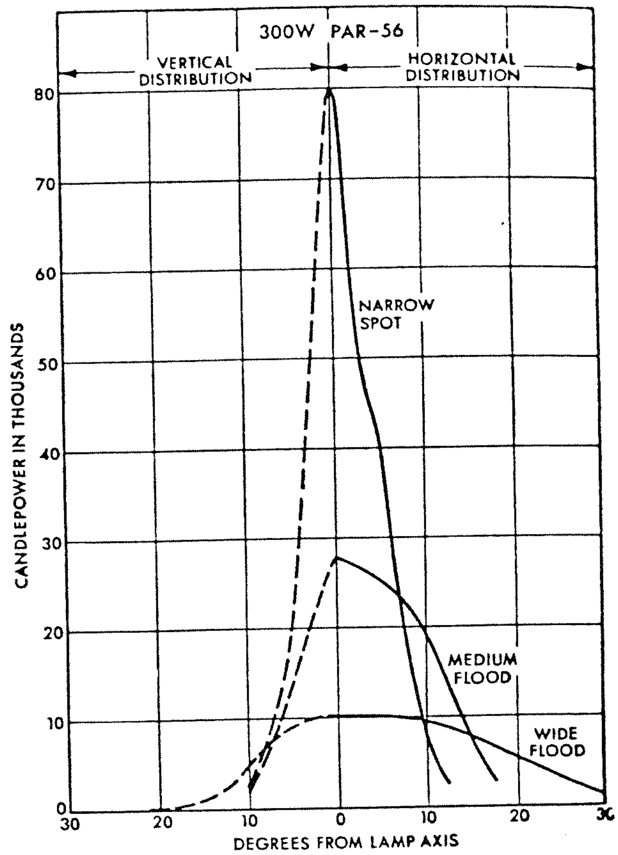
SPOTLIGHT AND FLOODLIGHT - (CONTD.)

systems and must be burned in positions for which they are designed, to avoid premature failures.

REFLECTORIZED

These lamps include those made in standard and special bulb shapes and which have a reflecting coating directly applied to part of the bulb surface. Both silver and aluminum coatings are used. Silver coatings may be applied internally or externally, and in the latter case the silver coating is protected by an electrolytically-applied copper coating and sprayed aluminum finish. Aluminum coatings are applied internally by condensation of vaporized aluminum on the bulb surface.





Typical candlepower distribution characteristics of representative types of reflector and PAR lamps.

HIGH TEMPERATURE APPLIANCE

These lamps are specially constructed for high temperature service. The most common types are clear, medium base, 40-watt A-15 appliance and oven; 50-watt, A-19; and 100-watt, A-23 bake oven lamps. Range oven lamps are designed to withstand oven temperatures up to 475° F and bake oven up to 600° F.

ROUGH SERVICE

To provide the resistance to filament breakage as required for portable extension cords, etc., rough service lamps employ special, multiple-filament-support construction. Because of the number of supports, the heat loss is higher and the efficacy lower than for general service lamps.

In using miniature lamps where rough service conditions are encountered, bayonet and wedge base lamps should be chosen instead of screw base lamps. Bayonet and wedge base lamps lock in the socket whereas screw base lamps tend to work loose.

VIBRATION SERVICE

Most lamps have coiled filaments made of tungsten having high sag resistance. Vibration lamps, designed for use where high-frequency vibrations would cause early failure of general service lamps, are made with a more flexible tungsten filament. The sagging characteristics of the wire used allow the coils to open up under vibration, thus preventing short circuits between coils.

Miniature radio panel lamps of 6.3 volts and under, incorporate mounts whose resonant frequency has been synchronized with that of the coiled filament to withstand shock and vibration.

VIBRATION SERVICE - (CONTD.)

Vibration and shock frequently accompany each other and sometimes only experiment will determine the best lamp for the purpose. Vibration-resisting sockets or equipment, utilizing a coiled spring or other flexible material to deaden vibration, have been employed where general service lamps are used under conditions of severe vibration.

LUMILINE

The lumiline lamp has a tubular bulb and two disk bases: one at each end of the lamp, with the filament connected between them. The filament, in the form of a stretched coil, is supported on glass insulating beads along a small metal channel within the bulb. The 30-and 60-watt sizes are available in the 18-inch length. The 40-watt lamp is made in a 12-inch length. All sizes are available in either clear or inside-frosted tubes as well as white and various color coatings.

SHOWCASE

These use tubular bulbs and conventional screw bases. The longer lamps have elongated filaments with filament supports similar to lumiline lamps. The common sizes are 25- and 40-watt, but sizes up to 75 watts are available.

THREE-LITE

These lamps employ two filaments, operated separately or in combination to provide three levels of illumination. The common lead-in wire is connected to the shell of the base; the other end of one filament is connected to a ring contact, and the end of the

THREE-LITE - (CONTD.)

other filament to a center contact. Three-lite lamps are available in several different wattage ratings.

SIGN

While large numbers of gas-filled lamps are used in enclosed and other types of electric signs, those designated particularly as "sign" lamps are mostly of the vacuum type. Lamps of this type are best adapted for exposed sign and festoon service because the lower bulb temperature of vacuum lamps minimizes the occurrence of thermal cracks resulting from rain and snow. Some low-wattage lamps, however, are gas-filled for use in flashing signs. Bulb temperatures of these low-wattage, gas-filled lamps are sufficiently low to permit exposed outdoor use.

DECORATIVE

A wide variety of lamps for decorative applications is available from lamp manufacturers. Different bulb shapes, together with numerous colors and finishes, are used to achieve the desired appearance. Lamp manufacturers' catalogs should be consulted for information on the various decorative types.

SERIES STREET LIGHTING

Street series lamps are designed to operate in series on constant current circuits. The most common circuit uses 6.6 amperes, automatically regulated to maintain this value regardless of the number and size of the lamps in the circuit. Lamps for 15- and 20 ampere ratings usually are connected in the secondary of a transformer, the primary being in the 6.6 ampere circuit.

SERIES STREET LIGHTING - (CONTD.)

These lamps are designated by their initial lumen output and ampere rating; for example, the 2500-lumen, 6.6-ampere lamps, or the 6,000-lumen, 20-ampere lamps. Watt and volt ratings, as used to designate multiple lamps, are not commonly employed. Because the lumen output of series lamps is generally specified in street lighting contracts, improvements in light output are reflected by reductions in watts and volts. This usually results in odd numbers and fractions for volts and watts; for example, the present 2500-lumen, 6.6-ampere lamp would have an average rating of 21.5 volts and 142 watts.

MULTIPLE STREET LIGHTING

Multiple street lighting lamps are designed so that their mean lumens correspond approximately to the mean lumens of series lamps of the same initial lumen rating. Since the lamp's voltage is established by a multiple circuit, the watts come out in odd values in order to obtain the desired nominal lumen ratings.

TRAFFIC SIGNAL LAMPS

Lamps used in traffic signals are subjected to more severe service requirements than most applications of incandescent lamps. In order to provide uniformity of application, lamps must be compatible with the design requirements of optical systems of standard traffic signals.

AVIATION

Lighting for aviation is divided into two classes: lighting on and around airports, and lighting on aircraft.

In airport lighting, both multiple and series type lamps are used. Most new systems being installed use series type lamps of 6.6-ampere and 20-ampere designs for airport approach, runway, and taxiway lighting, whereas multiple lamps are used for obstruction, hazard beacon, and airport identification beacon lighting. On aircraft, small and miniature lamps are used exclusively for both interior and exterior lighting. Most of the lamps used in airport lighting are designed to be used in precise projection type equipment to produce a controlled beam of light complying with required standards. Hazard beacons and airport identification beacons signaling the presence of high obstructions or the whereabouts of the airport, use lamps of wattages ranging from 500 to 1200 watts. Lamps used on the airport proper range in size from 10 to 500 watts. Lamps used for aircraft lighting are in the miniature classification, although landing lamps as large as 1000 watts are used.

RIBBON FILAMENT LAMPS

Incandescent lamps made with ribbons or strips of tungsten for the filaments have been used in special applications where it is desirable to have a substantial area of fairly uniform luminance. Ribbon dimensions vary from 0.7 to 4 millimeters in width and up to 50 millimeters in length. The 5- to 20-ampere ribbon filament lamps are usually employed in recorders, instruments, oscillographs, and

RIBBON FILAMENT LAMPS - (CONTD.)

microscope illuminators. The 30- to 75- ampere lamps are used for pyrometer calibration standards and for spectro-graphic work.

MINIATURE LAMPS

The term "miniature" applied to light sources is really a lamp manufacturer's designation determined by the trade channels through which the lamps so identified are distributed, rather than by the size or characteristics of the lamps. In general, however, it is true that most miniature lamps are small, and consume relatively little power. The most notable exceptions to this generalization are the sealed-beam type lamps, some of which are classed as miniature lamps, even though they may be as large as eight inches in diameter and consume up to 1000 watts.

Sub-miniature lamps have increased in popularity. They range in size from T-2 down to T-1/8. Since early in World War II the T-1 3/4 has been used extensively for instruments and indicators. The T-1 size has become popular for aircraft instruments and indicators. The T-5/8 and small sizes down to T-1/8 are used chiefly in novelty application such as tiny flashlights, jewelry, etc. Most miniature incandescent filament lamps operate at voltages under 50 volts. These voltages may be obtained from batteries, generators, or circuits with low voltage transformers. However, miniature lamps may be used on 120-volt circuits when transformers, rectifiers, or resistors are used to reduce the voltage.

MINIATURE LAMPS - (CONTD.)

The mean effective voltage delivered by the battery or circuit is generally higher than average voltage and should be the design voltage of the lamp. Design voltages for flashlight lamps have been determined by extensive tests. Proper lamp and battery combinations are shown in manufacturers' catalogs.

With transformers or resistors, delivered rather than rated voltage must be precisely controlled in order to obtain proper lamp life and output. On resistor operation, because the delivered voltage increases as the filament evaporates, lamp life will generally be one-half of transformer operation.

FLASHLIGHT, HANDLANTERN, AND BICYCLE

These lamps are commonly operated from dry cell batteries having an open circuit voltage of 1.5 volts per cell for new batteries and dropping to approximately 0.9 volts per cell at the end of battery life. This results in a big difference in light output, depending upon whether the batteries are new or old.

AUTOMOTIVE

Lamps for most passenger vehicles, trucks, and coaches presently operate at 12 to 16 volts. The power source is a storage battery-rectified alternator system.

SEALED BEAM

These lamps contain filaments, lens and reflectors in a precise rugged optical package available in a wide variety of sizes in voltages ranging from 6 to 120 volts. Sealed beam or PAR lamp lenses are made of an oven-ware type glass. The reflector is vaporized aluminum on glass, hermetically sealed to the lens cover. The advantages are:

(1) accurate reflector contour for accurate beam control;

(2) precise filament positioning on rugged filament supports;

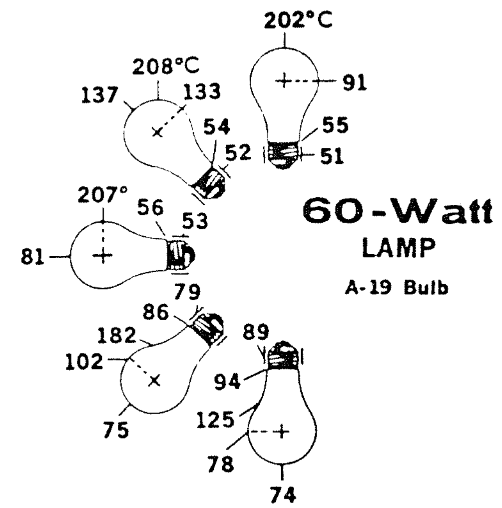
(3) high efficacy and excellent candlepower maintenance.

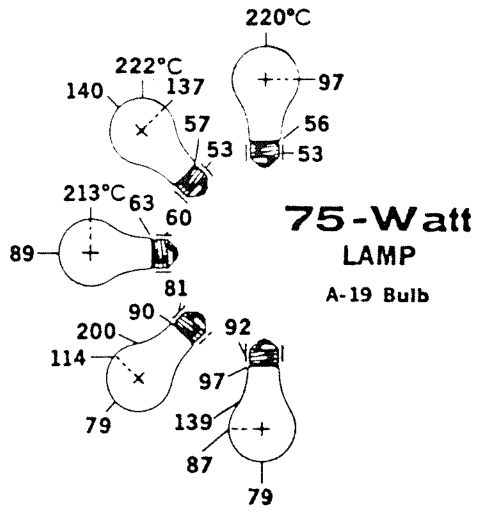
Vaporized aluminum on glass is an excellent reflector, does not deteriorate, and the normal bulb blackening has little effect on the candlepower output throughout lamp life. The sealed beam lamp is particularly suitable where a large amount of concentrated light at low voltage is required.

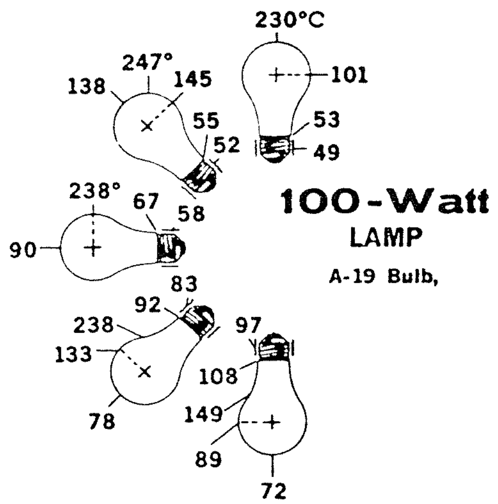
INDICATOR, RADIO AND TELEVISION

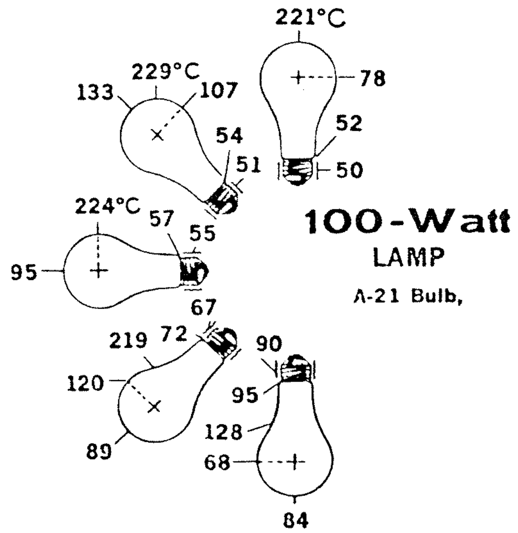
Lamps for indicator, radio and television service are usually operated from low voltage transformers.

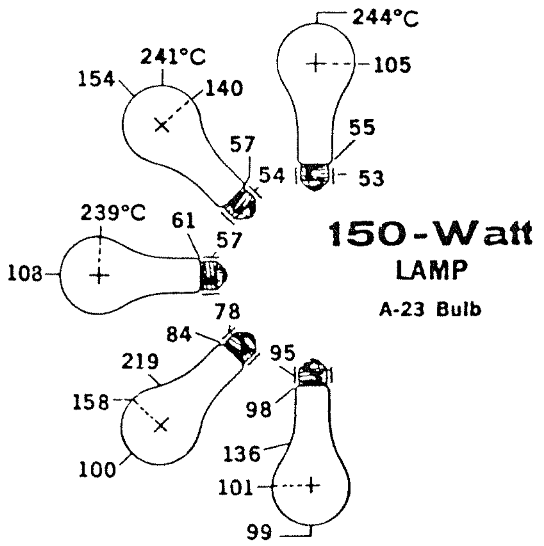
1.9 Bulb and Socket Temperatures for A Shape Lamps

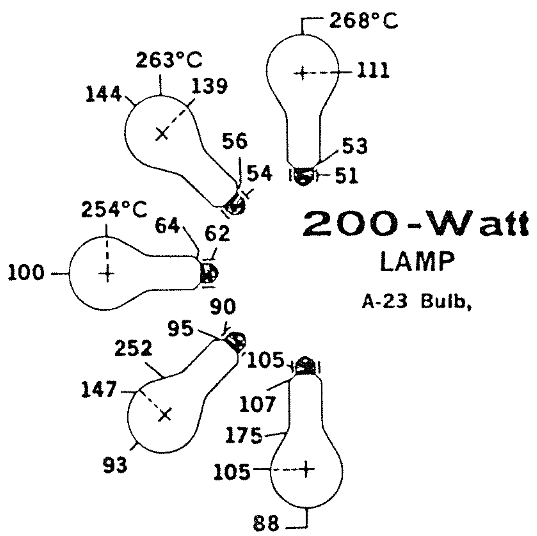




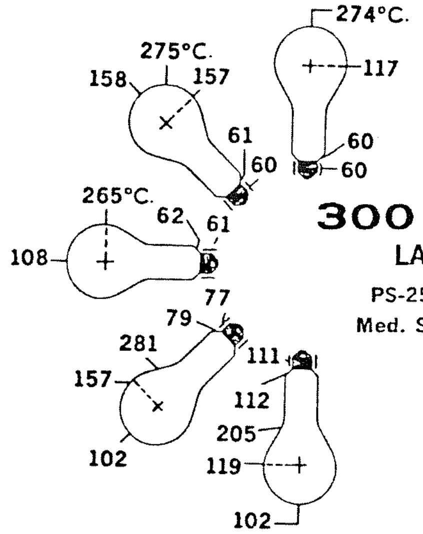




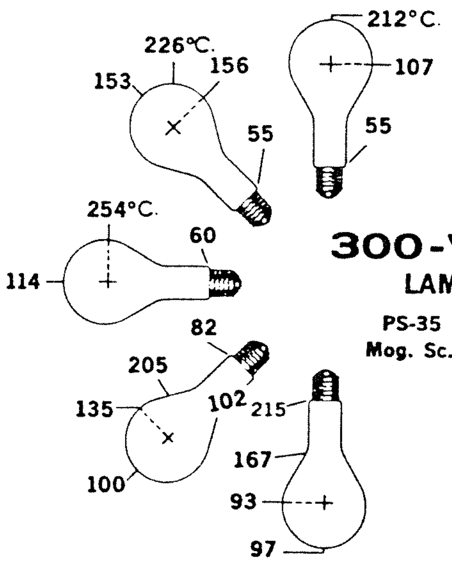




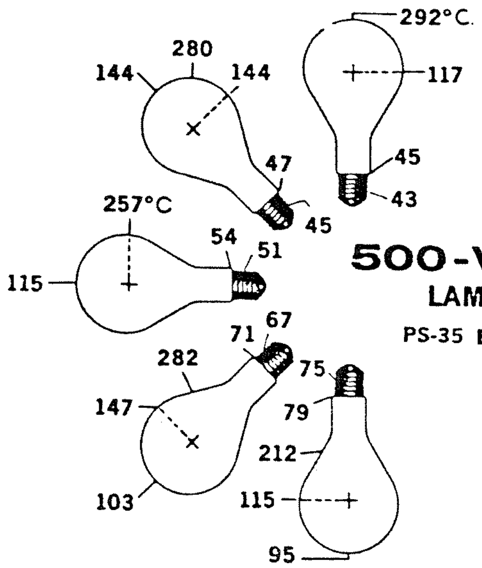
Bulb and Socket Temperatures for PS Shape Lamps



300-Watt LAMP
PS-25 Bulb, Med. Sc. Base



300-Watt LAMP
PS-35 Bulb, Mog. Sc. Base

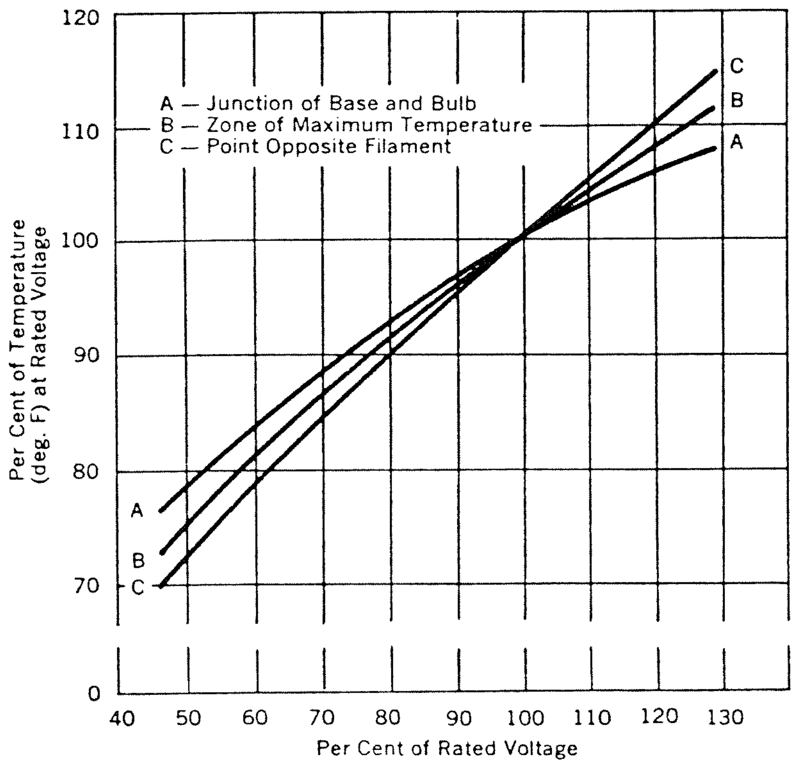


500-Watt LAMP
PS-35 Bulb

Relatively few lamp operating troubles are caused by excessive temperature. Some difficulties may arise, however, under extreme conditions of improper usage. These troubles include bulb blistering, base loosening, and thermal cracks because of localized cooling.
Overheating adjacent or surrounding equipment (e.g. wiring, sockets, etc.) may be a hazard.
The air temperature near a bare bulb does not increase appreciably. For example, the air temperature an inch away from a 100-watt lamp is only about 20 degrees higher than room temperature.
High bulb temperature usually does not affect the life of the lamp unless this temperature is extreme. The filament operates at a very high temperature (near 4750°F for a 200-watt lamp). An increase of a few hundred degrees in bulb temperature does not noticeably increase the filament temperature, and there is practically no effect on the lamp life or light output.
Glass in most general service bulbs withstands 700°F safely; various heat-resistant glass compositions withstand temperatures from 855°F to 975°F.

lamp temperature vs. voltage

The temperature of a gas-filled lamp at any point varies with the wattage, which is dependent on voltage. The temperature of all points on the bulb increases as the voltage increases, as shown by these curves; the temperature, however, does not change as rapidly as the voltage.



1.10 REFERENCES FOR ADDITIONAL INDEPTH INFORMATION

1. IES Lighting Handbook from IES Society

2. Internal Testing Specifications for A-Line Lamps, GTE Sylvania, Loring Ave., Salem, Mass.

TEST	SPECIFICATION #
Basing Cement - Boiling Water	2E0300-6
Torque Test for Bases	2E0404-711-712A
Puff Test for Detection of Oxygen	2E0602-13
Hot Shock Test	2E0602-3B
Vibration and Pendulum Bump Test	2E0602-15B
Vibration Test	2E0602-2E
Variable Drop Test	2E0602-11D
Overnight Age and Bump Test	2E0602-1C
Standard Method for Designating Nature and Position of Failure of Lamps	2E0601-4A

3. SAE Handbook - Lighting Equipment and Photometric Tests. Society of Automotive Engineers, Two Pennsylvania Plaza, New York, N. Y. 10001

4. International Electrotechnical Commission Publication 64, Tungsten Lamps for General Service.

5. General Electric Component Technology and Standardization - Section 11.0.

6. Internal Reports by D. Dayton, GTE Sylvania, Danvers, Mass. 01923

7. Method of Detecting Oxygen Contaminant in Sealed Envelopes, U. S. Patent #3, 194, 110.

8. Cyanogen Contamination Test by S. F. Boyd (1973), GTE Sylvania, Loring Avenue, Salem, MA. 01970

9. Emission Test of RF Excited Lamps by E. F. Wyner, Report #E-4813 GTE Sylvania, T & M Group, Danvers, MA. 01923

REFERENCES FOR ADDITIONAL INDEPTH INFORMATION

10. The Life-Voltage Exponent for Tungsten Lamps by E. J. Covington Journal of IES - Jan. 1973, Pg. 83.

11. Mathematical and Physical Boxes for Incandescent Lamp Exponents by Donald D. Van Horn, Journal of IES, April, 1965.

12. The Scientific Basis of Illuminating Engineering by P. Moon, Dover Publications, Inc., N. Y., 1961.

13. The Collected Works of Irving Langmuir, Vol. II., Pergamon Press

14. Characteristic Equations of Vacuum and Gas-Filled Tungsten Filament Lamps, Journal of the National Bureau of Standards, Vol. 9, Pg. 721, 1932.

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16. Colorimetry by C. W. Jerome - GTE Sylvania, Danvers, Mass., 01923

17. Lamp Manufacturers Bulletin - GTE Sylvania, General Electric, Westinghouse, Philips, Thorn, G.E.C.

18. Thermonic Emission in Gas-Filled Incandescent Lamps by R.H. Clapp GTE Sylvania, Danvers, Mass. 01923

19. Detection of Hydrocarbons in Lamp Filling Gases by J. R. Coaton Thorn Lighting Limited, 1974.

20. Early Photometric and Electrical Changes in Incandescent Lamps and Their Relationship to Surface Characteristics of Tungsten Lamps by F. H. Eppig and N. Loucaides, IES Journal, 1972.

21. What Happens During Seasoning of an Incandescent Lamp? by D. Dayton, GTE Sylvania, Danvers, Mass., 1976

22. Black Wire vs. Clean Wire for Incandescent Lamps, by D. Dayton, GTE Sylvania, Danvers, Mass., 1976

REFERENCES FOR ADDITIONAL INDEPTH INFORMATION

23. Internal Paper "Flashing" by K. R. Bagley, GTE Sylvania, Loring Ave., Salem, Mass., 01970.

24. Incandescent Lamps by W. G. Matheson, GTE Sylvania, Danvers, Mass., 01923.

25. Training Program for Flashing Procedures and Equipment Available from GTE Sylvania Equipment Development Plant, Ipswich, Mass., 01938

26. Internal Testing Specifications for Incandescent Lamps, GTE Sylvania, Loring Ave., Salem, Mass., 01970.

Photometer Procedure Spec. #2E0501-4

Regular Checks on Photometry Spec. #2E0200-1

THE FILAMENT

2.0 The filament is sometimes called the "coil", or in Europe, the "spiral". The filament may be a straight wire, or strip, a coil or a coiled coil. The filament is the heart of an incandescent lamp. All other parts of the lamp serve only to either supply power or protect the environment of the filament.

The environment surrounding the filament is either vacuum or an inert gas. Gas-filling reduces tungsten evaporation by a factor of about 100 times.

In all cases, the basic properties of tungsten control the design of the filament and the performance of an incandescent lamp.

The following tables show the properties of tungsten as a function of true degrees Kelven.

Table IV is data for vacuum lamps and Table V is data for gas-filled GLS lamps.

Coiled filaments by virtue of their geometry do not expose all wire surface to radiate. The "effective surface area" of a coil can be calculated if its temperature and light output is known by dividing its total light output by the flux D in lumens/cm^2 corresponding to its temperature.

Conversely, the "effective surface area" of a coil can be estimated from its geometry and used with columns J, LPW and D of Table V to estimate its performance.

TABLE IV

PROPERTIES OF TUNGSTEN IN VACUUM

T (°K)	Resistivity ρ Microhm-cm	J Watts/sq cm	L.P.W. Lumens/watt	D Lumens/sq cm
1000	24.93	0.602	0.000693	.00131
1100	27.94	1.027	0.00344	.0111
1200	30.98	1.66	0.0126	.0655
1300	34.08	2.57	0.0355	.286
1400	37.19	3.83	0.0899	1.08
1500	40.36	5.52	0.199	3.44
1600	43.55	7.74	0.395	9.60
1700	46.78	10.62	0.724	24.1
1800	50.05	14.19	1.19	53.0
1900	53.35	18.64	1.94	113.3
2000	56.67	24.04	2.84	214.0
2100	60.06	30.5	4.08	391.0
2200	63.48	38.2	5.52	662.0
2300	66.91	47.2	7.24	1073.0
2400	70.39	57.7	9.39	1702.0
2500	73.91	69.8	11.72	2567.
2600	77.49	83.8	14.34	3770.
2700	81.04	99.6	17.60	5510.
2800	84.70	117.6	20.53	7575.
2900	88.33	137.8	23.64	10220.
3000	92.04	160.5	27.25	13720.
3100	95.76	185.8	30.95	18070.
3200	99.54	214.0	34.70	23300.
3300	103.3	245.4	38.90	29950.
3400	107.2	280.0	43.20	37880.
3500	111.1	318.0	47.15	47000.
3600	115.0	360.0	50.70	57250.
3655	117.1	382.6	53.10	63800.

TABLE V

PROPERTIES OF TUNGSTEN IN GAS FILLED LAMPS

T (°K)	Resistivity ρ Microhm-cm	J Watts/sq cm	L.P.W. Lumens/watt	D Lumens/sq cm
1000	24.93	0.602	0.00055	.00131
1100	27.94	1.027	0.00275	.0111
1200	30.98	1.66	0.010	.0655
1300	34.08	2.57	0.0284	.286
1400	37.19	3.83	0.072	1.08
1500	40.36	5.52	0.160	3.44
1600	43.55	7.74	0.316	9.60
1700	46.78	10.62	0.579	24.1
1800	50.05	14.19	0.952	53.0
1900	53.35	18.64	1.55	113.3
2000	56.67	24.04	2.272	214.0
2100	60.06	30.5	3.264	391.0
2200	63.48	38.2	4.416	662.0
2300	66.91	47.2	5.792	1073.0
2400	70.39	57.7	7.512	1702.0
2500	73.91	69.8	9.376	2567.
2600	77.49	83.8	11.472	3770.
2700	81.04	99.6	14.08	5510.
2800	84.70	117.6	16.42	7575.
2900	88.33	137.8	18.91	10220.
3000	92.04	160.5	21.80	13720.
3100	95.76	185.8	24.76	18070.
3200	99.54	214.0	27.76	23300.
3300	103.3	245.4	31.12	29950.
3400	107.2	280.0	34.56	37880.
3500	111.1	318.0	37.72	47000.
3600	115.0	360.0	40.56	57250.
3655	117.1	382.6	42.48	63800.

SHOULD LAMP BE VACUUM OR GAS-FILLED?

2.1 A vacuum lamp loses energy mainly by radiation; only a small fraction is lost to leads by conduction.

A gas-filled lamp loses energy by radiation, lead losses and to the gas-fill by conduction and convection. Gas losses result from the flow of filling gases in a convection stream past the filament, rising to the top of the bulb and circulating down the sides. The gas carries heat away from the filament, and transfers some of this heat to the bulb wall.

The amount of heat loss to fill-gas in a given lamp varies with coil temperature, coil geometry, type of fill-gas, coil orientation, lamp current and bulb size. The major factor is the filament wire size. A coiled coil filament has less gas loss than a single coil. The following table shows a general comparison of two equal lamps where one lamp is at vacuum and the other gas-filled.

	VACUUM	GAS-FILLED
Bulb Size	Bigger	Smaller
Filament Wire Size	Bigger	Smaller
Filament Temperature	Lower	Higher
Tungsten Evaporation Rate	Higher	Lower

Gas filling to about one atmosphere reduces evaporation of tungsten by a factor of about 100 times, and hence prolongs life at a given temperature. When designed for equal life, the higher filament temperature then permits higher efficacy in spite of the additional loss by convection to the gas.

The reduction in evaporation rate due to the gas fill is the controlling factor. Vacuum lamps have a present maximum efficiency of about 10 LPW. In this area, a reduction in evaporation rate of

2.1 (CONTD.)

100K means a filament wire in a gas filled lamp could run at a temperature about 300°K higher than a filament in a vacuum lamp and have equal life.

In terms of gas loss, the 300°K would result in an intrinsic brightness increase of 323% or an effective surface area reduction of 323% in the gas filled lamp. Since watts radiated in a vacuum lamp must equal watts radiated in a gas filled lamp plus gas loss watts, if the watts radiated/cm^2 in a vacuum lamp is approximately 57.7 watts/cm^2 and watts radiated/cm^2 in gas filled lamp is 99.6 watts/cm^2 it follows that

$$57.7 \times 1 = \text{Vacuum lamp radiation loss}$$

$$99.6 \times \frac{1}{3.23} = \text{Gas filled lamp radiation loss} = 30.76 \text{ watts}$$

$$\frac{57.7 - 30.76}{57.7} = 46.68\% \text{ gas loss}$$

The calculation shows that a gas filled lamp could have almost 50% of its input energy lost to the gas fill and still have equal life and lumens.

The published values of the gas loss are as follows:

Lamp Watts	Lamp Current	Gas Loss %	Lead Loss %	Bulb & Base Loss %
40	.3636A	20	1.6	7.1
60	.5454A	13.5	1.2	4.5
100	.9090A	11.5	1.3	5.2
200	1.8181A	13.7	1.7	7.2

NOTE: 60 and 100 watt lamps have coiled coil filaments, 40 and 200 watt lamps have C-9 filaments.

2.1 (CONTD.)

The above values were arrived at by simply taking tubulated lamps and measuring watts at equal lumens as a vacuum lamp and as a gas filled lamp and calculating gas loss % as follows:

$$\frac{\text{Watts (Gas filled)} - \text{Watts (Vacuum)}}{\text{Watts (Gas filled)}} \times 100 = \text{Gas loss \%}$$

This method determines the gas loss for a particular lamp but does not indicate the gas loss for two lamps of equal wattage and lumens where one lamp is gas filled and the other vacuum.

The following table compares the design of a 40 watt, 120 volt, 11.5 LPW vacuum lamp and an equal gas filled lamp.

	Vacuum Lamp	Gas Filled Lamp
Wire Weight	6.32 mg/200	3.9588 mg/200
Wire Diameter	.00458 cm	.003626 cm
Wire Length	69.8 cm	52. cm
Total Surface Area	1.00452 cm^2	.59457 cm^2

The lumens of both lamps are equal. 460 measured lumens and approximately 500 actual lumen. The lumens are a product of the intrinsic brightness of tungsten in lumens/cm^2 and the effective area of the filament. The intrinsic brightness varies with temperature. The value for the vacuum lamp will be approximately 1250 lumens/cm^2 and effective area of coil is approximately .40 cm^2. The total watts radiated is directly related to the intrinsic brightness. The total watts radiated by the vacuum lamp is approximately 84.83 watts/cm^2.

2.1 (CONTD.)

Watts radiated vacuum = 84.83 x .40 = 33.9 watts

The effective surface of the gas filled lamp is .2372 cm^2 or 59% of the vacuum lamp area. Since the luminous radiation is the same, the intrinsic brightness of the gas filled lamp will be 2107 $lumen/cm^2$. On this basis, the watts radiated will be 108.17 $watts/cm^2$.

Watts radiated gas filled = 108.17 x .2372 = 25.66 watts

Therefore, the gas loss is 33.9 watts - 25.66 watts or 8.24 watts. The gas loss is 24%.

The following table shows the gas loss % of equal vacuum and gas filled lamps. All lamps have single coil C-9 filaments.

Watts	Gas Loss %
25	35.5
40	24
100	22

The maximum allowable gas loss of 46% for single coils will not be reached until wattage drops below 25 watts or .208 amps.

1. For single coils, the crossover point is about 18 watts (.15A).
2. For coiled coil lamps, the crossover point is about 12 watts (.10A).

2.1 - (CONTD.)

This means that for single coils, lamps below .15 amps must be vacuum for maximum lumens at a given life and that for coiled coil filaments, lamps below .10 amps must be vacuum for maximum lumens at a given life. The data also shows that a coiled coil gas-filled lamp is superior to a single coil vacuum lamp at any current above .10 amps.

2.2 FILAMENT GEOMETRY

The shape of geometry of the filament is determined by the length of the filament, the size of the bulb, the wattage and the application of the incandescent lamp.

Table VI shows some common filament types and their typical applications. Figures 2.2.1, 2.2.2 and 2.2.3 show some additional types and the geometry of the light distribution that results from various geometric configurations.

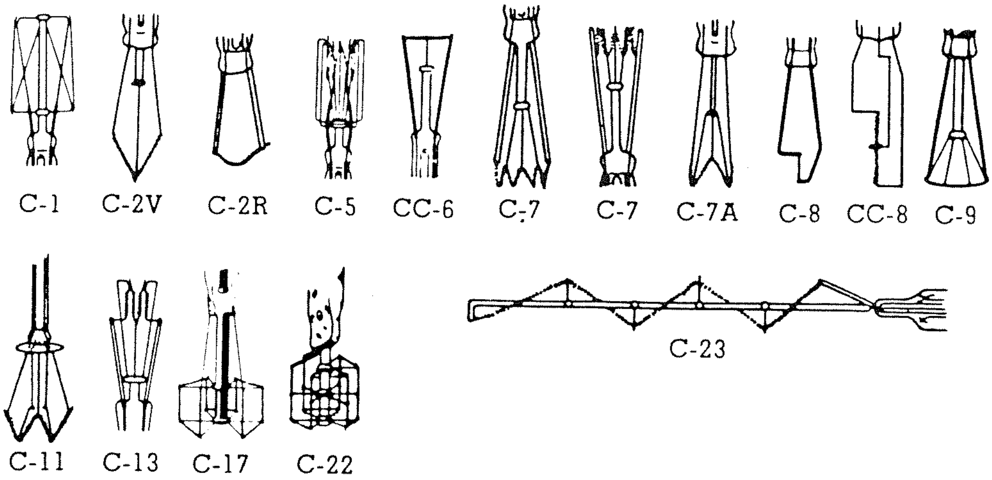


TABLE VI

VARIOUS INCANDESCENT LAMP FILAMENTS

Filament Designation	Description	Typical Lamp Using This Filament
C-1	Fairly long coiled filament, well supported.	15W, S-11, 75V, Train
C-2V	Fairly short coiled filament which requires one support.	6000 lumen, PS-40, Street Series
C-2R (Rounded)	Short filament, slightly rounded, requiring no supports.	30 volt, A-21 Street Railway
C-5	Concentrated filament for small light sources.	500W, G-40 Spot or Flood
C-6	Short coiled filament requiring few or no supports.	50W, A-21, 6 volt
CC-6	Short coiled-coil filament requiring few supports.	60W, A-19
C-7	Fairly long filament supported at top for base up burning.	10,000 lumen, PS-40, base up 20 amp., St. Series
C-7	Fairly long filament supported at bottom for base down burning.	10,000 lumen, PS-40, base down 20 amp., St. Series
C-7A	Long filament supported top and bottom for universal burning.	500W, PS-40, 230 volt
C-8	Coiled filament mounted along axis of bulb. May be elongated as in lumiline lamps.	25W, T-10, Showcase
CC-8	Short coiled-coil filament along axis of bulbs.	100W, A-19
C-9	Filament of average length, well supported. Semicircular. Also used for vibration service.	25W, A-19
C-11	Concentrated filament of some length. Well supported. "M" — shaped.	250W, G-30, Infrared
C-13	Monoplane filament, high concentrated for peojection equipment.	500W, T-20, Spotlight
C-17	Long filament requiring more than average number of supports.	100W, A-21, Rough Service
C-22	Long filament with extra supports for resistance to physical shock.	50W, A-19, Rough Service
C-23	Coiled filament mounted along axis of bulb and alternated along the length.	40W, T-8, Showcase

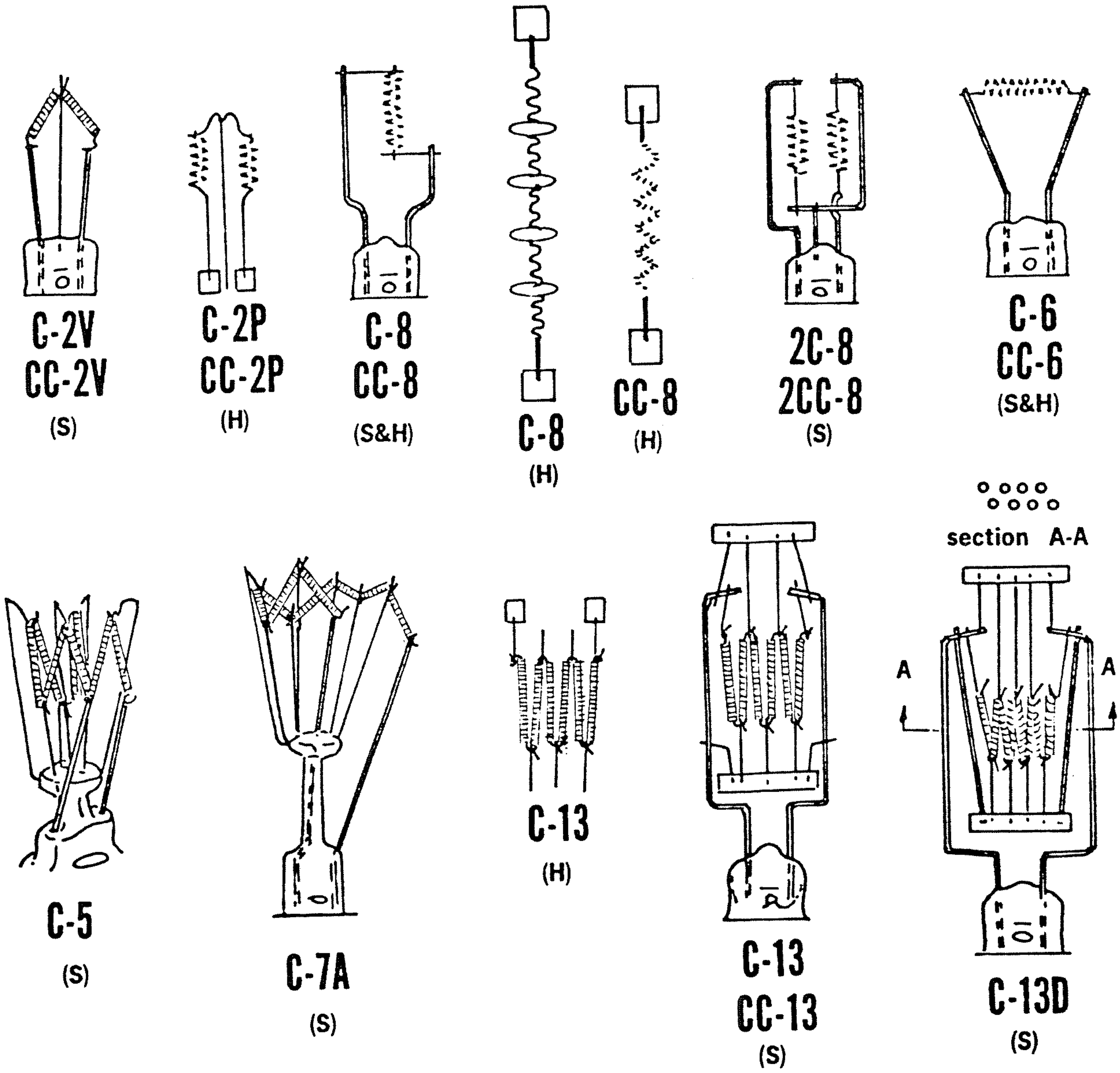
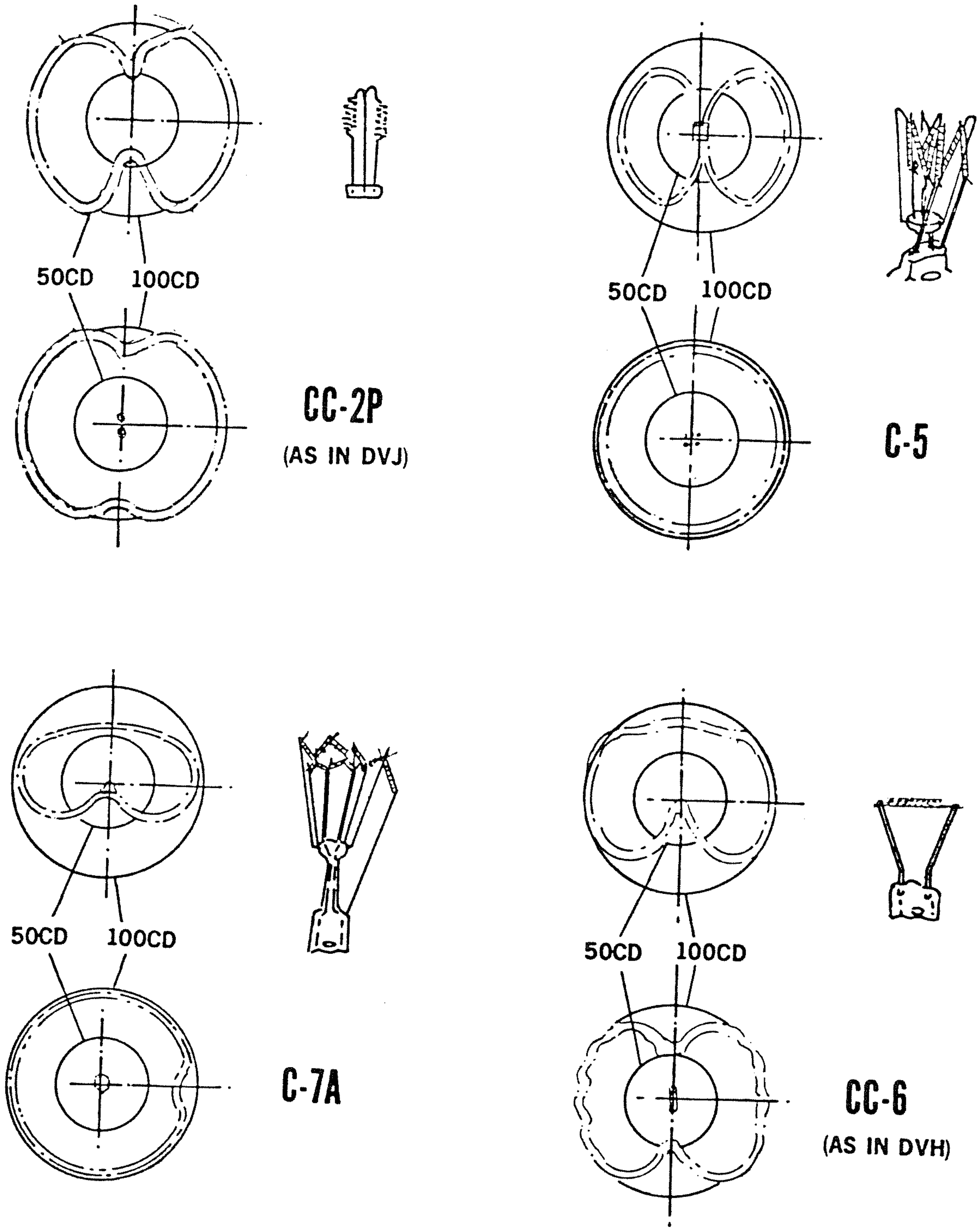


Figure 2.2.1 Filament forms most commonly used in lamps for studio lighting. They are identified by two-part designations: a descriptive letter prefix such as "C" (when the filament wire is coiled before mounting), or "CC" (coiled coil), plus an arbitrary number or number-letter suffix that identifies the configuration of the filament and the supporting structure, and their relation to the lamp axis. The letter (S) or (H) indicate whether the particular filament form is primarily associated with standard (S) or halogen-cycle (H) lamps. Proportions of filaments and details of mount structures in specific lamps may vary considerably from the illustrations.



<u>Figure 2.2.2</u> Generalized polar distribution of candlepower for several of the filament types of Figure 2.2.1. Circular reference lines indicate intensity values of 50 and 100 candelas per 1000 lumens of total emitted light. Angles of measurement are in plane of paper when filament is oriented as indicated in the center of each polar plot. Curves are of typical lamps with each filament form; specific lamp types may have considerably different distributions.

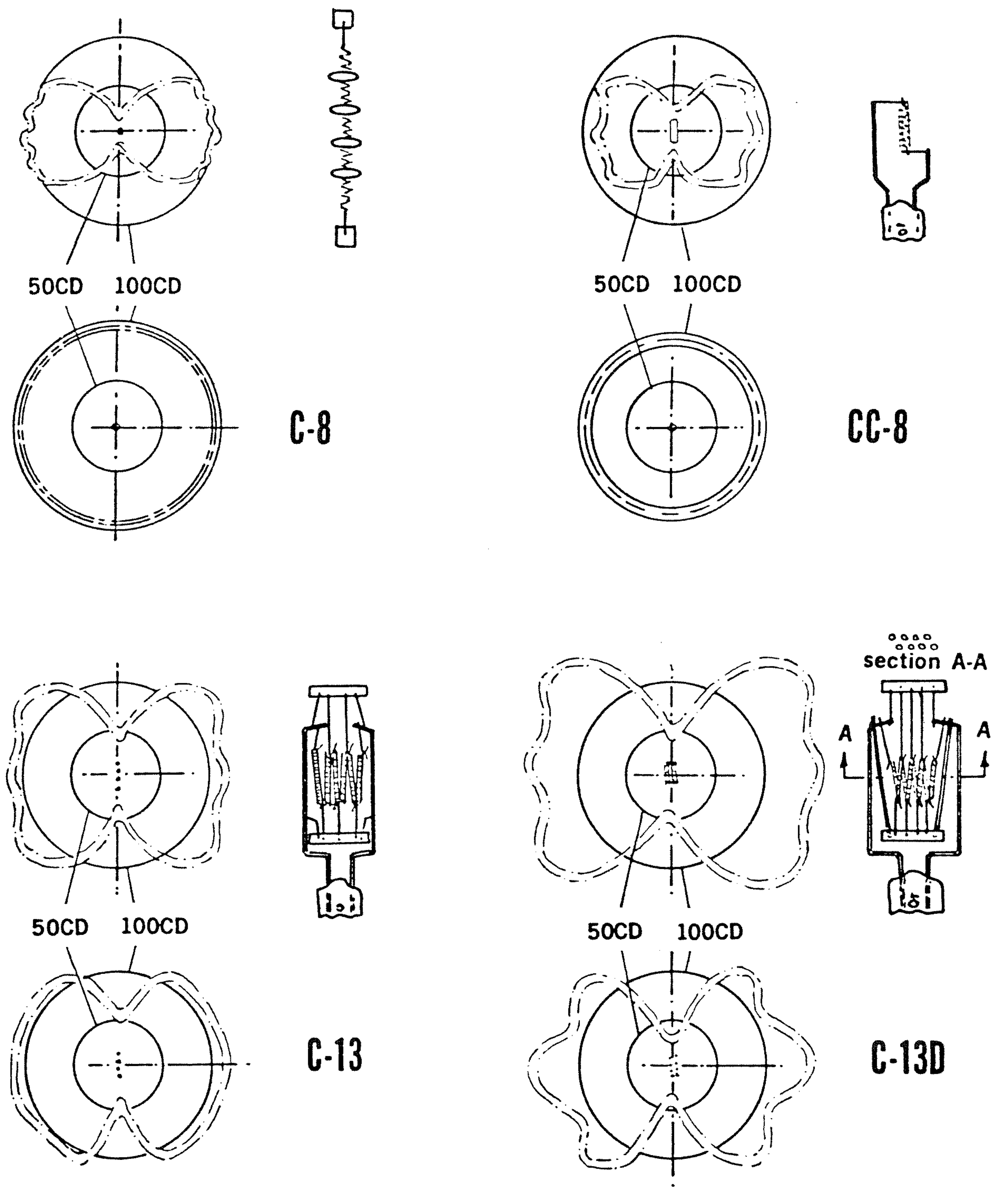


Figure 2.2.3 Generalized polar distribution of candlepower for several of the filament types of Figure 2.2.1. Circular reference lines indicate intensity values of 50 and 100 candelas per 1000 lumens of total emitted light. Angles of measurement are in plane of paper when filament is oriented as indicated in the center of each polar plot. Curves are of typical lamps with each filament form; specific lamp types may have considerably different distributions.

FILAMENT DESIGN

2.3 Tungsten is used for lamp filaments because of its high melting point and other necessary properties. Filament design is based on tungsten properties indicated on Table IV for vacuum lamps and Table V for gas-filled lamps.

In general, filaments absorb power on the inside of the wire and dissipate the power by radiation from the surface. The wire surface then is the major control in balancing wire temperature with a given power input.

Watts x lpw = Lumens/cm^2(D) x effective area of wire or coil.

Watts = Power or heat radiated/cm^2 (J) x effective area of wire or coil.

D & J are functions of the temperature of tungsten and are found in Table IV and V (properties of tungsten as a Function of Temperature).

A vacuum lamp dissipates most of the input power by radiation and a gas-filled lamp dissipates power by radiations plus conduction by the fill gas. The lamp or filament resistance R can be calculated for a selected filament temperature ^oK.

$$R = \frac{\rho \times 4 \times l \times 10^{-6}}{\pi d^2}$$

R = ohms

ρ = Hot resistivity of tungsten from Table IV or V in Microhm-cm.

l = length of filament wire in cm.

d = diameter of filament wire in cm.

2.3 FILAMENT DESIGN - (CONTD.)

$$\text{Ohm's Law} \quad I = \frac{E}{R}$$

$$\text{Watts} = I^2R = IE$$

2.3.1 FILAMENT DESIGN FOR VACUUM LAMPS WITHOUT REFERENCE LAMP DATA

The coil design is based on the actual temperature of the coil or the efficacy of the coil (lpw). The lamps are rated on their measured light output. The difference is due to light absorbed by the glass envelope, shadowed and absorbed by the base.

Actual Lpw = Measured Lpw + losses.

The losses vary by bulb size, base size, filament geometry, etc. Wire size is the basic calculation for filament design. Since small wires cannot be measured easily to determine the diameter, a given length of the wire (200 mm) is weighed and the diameter calculated.

Wire Weight in Mg/200 mm = 1.943 x (wire diameter in mils)^2

Wire Weight in Mg/200 mm = 0.003 x (wire diameter in micron)^2
(meters (M))

Most of all wire for lamps is designated in wire weight (W_w). Wire length is measured in mm.

For filament design calculation, the length is the effective length (L) or lighted length. Extra length for legs etc. are added to effective length to get total filament length (TFL).

TFL = Effective length + legs etc.

2.3.1 FILAMENT DESIGN (CONTD.)

Miniature and Sub-miniature Vacuum Lamps

Mount types C-6, C-2V, C-2R, or C-2F

$$W_w = \frac{19.83\ A\ I^{1.239}}{lpw^{.2588}}$$

Where A = Pitch Factor from Table VII
I = Lamp Current in AMPS
E = Design Voltage
lpw = measured lpw

$$L = \frac{13.22\ A\ I^{1/3}\ E}{lpw^{.5}}$$

NOTE: $\frac{MSCP\ (4\pi)}{IE} = lpw$

Large (A-Line) Vacuum Lamps

Mount Type C-9

Less Than 1 AMP Lamp Current

$$Ww = \frac{50.59\ A\ I^{1.471}}{(1.069\ lpw)^{.429}}$$

$$L = \frac{18.32\ A\ E\ I^{0.368}}{(1.069\ lpw)^{.54}}$$

More Than 1 AMP Lamp Current

$$Ww = \frac{50.59\ A\ I^{1.333}}{(1.069\ lpw)^{.429}}$$

$$L = \frac{18.32\ AEI^{1/3}}{(1.069\ lpw)^{.54}}$$

2.3.2 FILAMENT DESIGN FOR GAS-FILLED LAMPS WITHOUT REFERENCE LAMP DATA

The filament wire for a gas-filled lamp is smaller and runs at a higher temperature than for a comparable vacuum lamp. The energy dissipating area is smaller to compensate for the conductive losses and the filament runs hotter to get the same number of lumens.

From Table V (Tungsten Properties as a Function of Temperature) the lumens per cm^2 increase exponentially with temperature.

MINIATURE AND LARGE GAS-FILLED LAMPS

Mount Type C-6, C-2R, or C-2V

Less Than 1 AMP Lamp Current

$$Ww = \frac{31.36\ A\ I^{1.769}}{lpw^{.429}}$$

$$L = \frac{12.20\ A\ I^{0.442}\ E}{lpw^{.54}}$$

Greater Than 1 AMP Lamp Current

$$Ww = \frac{31.36\ A\ I^{1.333}}{lpw^{.429}}$$

$$L = \frac{12.20\ A\ I^{1/3} E}{lpw^{.54}}$$

Mount Type C-9

Less Than 1 AMP Lamp Current

$$Ww = \frac{31.69\ A\ I^{1.471}}{lpw^{.429}}$$

$$L = \frac{13.69\ A\ E\ I^{.368}}{lpw^{.54}}$$

Greater Than 1 AMP Lamp Current

$$Ww = \frac{31.69\ A\ I^{1.333}}{lpw^{.429}}$$

$$L = \frac{13.69\ A\ E\ I^{1/3}}{lpw^{.54}}$$

Where A = Pitch Factor from Table VII
E = Design Voltage
I = Lamp Current in AMPS
lpw = Measured lpw

NOTE: $lpw = \frac{MSCP\ (4\pi)}{I\ E}$

2.3.2 FILAMENT DESIGN (CONTD.)

LARGE GAS-FILLED LAMPS

Mount Type CC-8

Less Than 1 AMP Lamp Current

$$Ww = \frac{27.25\ A\ B\ I^{1.424}}{(1.1\ lpw)^{.495}}$$

$$L = \frac{9.863\ A\ B\ E\ I^{.348}}{(1.1\ lpw)^{.54}}$$

Greater Than 1 AMP Lamp Current

$$Ww = \frac{27.25\ A\ B\ I^{1.3633}}{(1.1\ lpw)^{.495}}$$

$$L = \frac{9.863\ A\ B\ E\ I^{1/3}}{(1.1\ lpw)^{.54}}$$

Mount Type CC-9 (European Type)

Less Than 1 AMP Lamp Current

$$Ww = \frac{27.52\ A\ B\ I^{1.424}}{(1.07\ lpw)^{.495}}$$

$$L = \frac{9.863\ A\ B\ E\ I^{.348}}{(1.07\ lpw)^{.54}}$$

Greater Than 1 AMP Lamp Current

$$Ww = \frac{27.52\ A\ B\ I^{1.3633}}{(1.07\ lpw)^{.495}}$$

$$L = \frac{9.863\ A\ B\ E\ I^{1/3}}{(1.07\ lpw)^{.54}}$$

Where A = Primary Pitch Factor from Table VII
B = Secondary Pitch Factor from Table VII
E = Design Volts
I = Lamp Current
lpw = Measured lpw

TABLE VII

PITCH FACTOR FOR COILED AND COILED COIL FILAMENTS

$$\text{PITCH \%} = \frac{100}{\text{TPI} \times (\text{d in inches})} \quad \text{or} \quad \frac{100}{\text{TP mm (d in mm)}}$$

TPI = Turns per inch

TPmm = Turns per millimeter

d = wire diameter

PITCH %	A (Primary or Single Coil) Pitch Factor	B (Secondary) Pitch Factor
125	1.844	
126	1.837	
127	1.830	
128	1.822	
129	1.815	
130	1.808	
131	1.801	
132	1.795	
133	1.788	
134	1.781	
135	1.775	
136	1.769	
137	1.763	
138	1.756	
139	1.750	
140	1.745	
141	1.739	
142	1.733	
143	1.727	
144	1.722	
145	1.716	
146	1.711	
147	1.706	
148	1.700	
149	1.695	
150	1.690	1.690
151	1.685	1.685
152	1.680	1.680
153	1.675	1.675
154	1.670	1.670
155	1.666	1.666

Note: Pitch % value is pitch as mounted including any stretch at mounting. For Coiled Coils, consider all stretch to take place in secondary coiling.

TABLE VII

PITCH %	A (Primary or Single Coil Pitch Factor	B (Secondary) Pitch Factor
156	1.661	1.661
157	1.656	1.656
158	1.652	1.652
159	1.647	1.647
160	1.643	1.643
161	1.639	1.639
162	1.634	1.634
163	1.630	1.630
164	1.626	1.626
165	1.622	1.622
166	1.617	1.617
167	1.613	1.613
168	1.609	1.609
169	1.605	1.605
170	1.601	1.601
171	1.598	1.598
172	1.594	1.594
173	1.590	1.590
174	1.586	1.586
175	1.583	1.583
176	1.579	1.579
177	1.575	1.575
178	1.572	1.572
179	1.568	1.568
180	1.565	1.565
200	1.502	1.502
225	1.439	1.439
250	1.388	1.388
275	1.346	1.346
INF or Straight Wire	1.000	1.000

2.3.3 FILAMENT DESIGN USING REFERENCE LAMP DATA

Filaments can be designed by making changes in existing lamp filament designs. If the reference lamp is a good design, the modified filament should be a good design also.

When designing by the reference lamp method, it is necessary to use the same % pitch of primary and secondary as was used to manufacture the reference lamp. Essentially, the filaments must be made similar in all respects.

The following formulas are the historic equations for designing filaments from reference data.

$$\text{Wire Wgt.} = \text{Ref. Wire Wgt.} \left[\frac{\text{Watts Desired}}{\text{Ref. Lamp Watt}}\right]^{a} \left[\frac{\text{Ref. Lamp Lpw}}{\text{Lpw Desired}}\right]^{b}$$

$$\text{Filament Length} = \text{Ref. Filament Length} \left[\frac{\text{Watts Desired}}{\text{Ref. Lamp Watts}}\right]^{c} \left[\frac{\text{Ref. Lamp Lpw}}{\text{Lpw Desired}}\right]^{d}$$

	For Vacuum Lamps	For Gas Filled Lamps
a	1.355	1.410
b	0.407	0.414
c	0.355	0.410
d	0.624	0.655

These exponents can only be used for small changes because they do not compensate for differences between single coil and coiled coil or low current and high current filament designs.

For more accuracy and greater changes from reference lamp data the following exponents can be used:

	For Micro and Subminiature Vacuum Lamps
a	1.239
b	0.259
c	0.333
d	0.500

FOR SINGLE COIL MINIATURE AND GLS VACUUM LAMPS WITH C-6 OR C-9 MOUNTS

	Less Than 1 AMP	Greater Than 1 AMP
a	1.470	1.333
b	0.429	0.429
c	0.368	0.333
d	0.540	0.540

FOR SINGLE COIL GAS-FILLED MINIATURE LAMPS C-6, C-2R OR C-25

	Less Than 1 AMP	Greater Than 1 AMP
a	1.769	1.333
b	0.429	.429
c	0.442	.333
d	0.540	.540

FOR SINGLE COIL GAS-FILLED LARGE LAMPS WITH C-9 MOUNT

	Less Than 1 AMP	Greater Than 1 AMP
a	1.471	1.333
b	.429	.429
c	.368	.333
d	.540	.540

FOR COILED COIL GAS-FILLED GLS LAMPS WITH CC-8 OR CC-9 (EUROPEAN) MOUNTS

	Less Than 1 AMP	Greater Than 1 AMP
a	1.424	1.363
b	0.495	0.495
c	0.348	0.333
d	0.540	0.540

2.4 FORMULA FOR MECHANICAL DESIGN OF FILAMENTS

LIST OF SYMBOLS

d = wire diameter

L = wire length

M = mandrel diameter

Pp% = primary pitch % of d

Pc = primary coil diameter

Sp% = secondary pitch % of Pc

N = number of turns

TPI = turns per inch

Pin = mandrel dia. for secondary coiling

Legs = uncoiled section of filament used for mounting

Overhang = extra wire or primary coiling extending beyond clamps

$\frac{M}{d}$ = mandrel to wire ratio primary or single coil

$\frac{Pin}{Pc}$ = second mandrel to primary coil ratio

Sc = secondary coil outside diameter

There are maximum and minimum accepted values for many of the parameters used in filament design and manufacturing.

Parameter	Range for Single Coil Design	Range for Coiled Coil Design
Pp	125 - 180%	150 - 180%
Sp		130 - 180%
$\frac{m}{d}$	2.5-6	1.7-2.2
$\frac{Pin}{Pc}$		1.36-2.2
Pin		254 μM (10 mils) min. for C-173 Equip.
Pin Pitch %		110% Minimum

These ranges are dictated by the "coilability" characteristics of tungsten wire on the one hand, and by the sag characteristics of the finished coil in the lamp on the other, and are empirical in nature based on many years of experience with the process.

$$\text{PITCH} = \frac{1}{\text{TPI}}$$

$$\%\ \text{PITCH} = \frac{100}{\text{TPI} \times d}$$

$$\text{TPI} = \frac{N}{\text{Coil Length in Inches}}$$

Number of Turns (N)

$$N = \frac{\text{Coil Length}}{\text{Pitch}}$$

$$\text{Length per Turn} = \sqrt{\pi^2 (m + d)^2 + \left[\frac{Pp}{100}\right]^2} = \sqrt{\pi^2 \left[\frac{m}{d} + 1\right]^2 + \left[\frac{Pp}{100}\right]^2}$$

or approx. $\pi \; (m + d)$ 1.5 - 2% error at typical % pitch and mandrel rates.

$$\text{Primary Coil Length or Cut Length} = \frac{L \times Pp\%}{100 \left[\frac{m}{d} + 1\right] \pi}$$

or for more accuracy

$$\text{Primary Coil Length or Cut Length} = \frac{L \times Pp\%}{100 \left[\pi^2 \left[\frac{m}{d} + 1\right]^2 + \left[\frac{Pp}{100}\right]^2\right]^{\frac{1}{2}}}$$

$$\text{Primary Coil Length} = N \times \frac{Pp\%}{100} \times d$$

Primary Coil Length = $\frac{1}{TPl}$ x N

Body Length of Coil-Coil = $\dfrac{L\ Pp\%\ \times\ Sp\%}{10^{4}\left[\frac{m}{d}+1\right]\left[\frac{Pin}{Pc}+1\right]^{2}}$

Total Filament Length (TFL)

$$TFL = \frac{(\text{Primary Coil Length} + \text{Legs} + \text{Overhang}\left[\frac{m}{d}+1\right] \quad X10^{2}}{Pp\%}$$

Coil Outside Diameter (Pc)

$$Pc = M + 2d$$

Coil Coil Outside Diameter (Sc)

$$Sc = \left[\frac{Pin}{Pc}+2\right]\left[\frac{m}{d}+2\right] X\ d$$

$$= Pin + 2Pc$$

Coil Coil Outside Pitch %

$$\text{CC Outside Pitch }\% = \frac{\left[\frac{Pin}{d}+2\right]\left[\frac{m}{d}+3\right]}{\left[\frac{Pin}{d}+\frac{m}{d}+2\right]} X\ \underline{Pp\%}$$

Coil Coil Inner Pitch or Pin Pitch %

$$\text{CC Inner Pitch }\% = \frac{\left[\frac{Pin}{d}+1\right]}{\left[\frac{Pin}{d}+\frac{m}{d}+2\right]} X\ \underline{Pp\%}$$

2.5 FILAMENT CORRECTION TECHNIQUE

It is often desirable to make small corrections in filaments to cope with a range of wire size (usually ± 3%) or to correct life or ratings.

When a change in wire size and length is necessary for a change in watts and/or lpw is required, the same procedure as used for designing filaments from reference data can be used. See 2.3.3. When a change in watts and/or lpw is desired without any change in wire size, a change in primary or secondary pitch can be used to correct the design. To use this procedure, perform the following steps:

1. Convert change in watts and lpw to change in wire weight and wire length.

$$\text{New Wire Wgt.} = \text{Old Wire Wgt.} \left[\frac{\text{Watts Desired}}{\text{Present Watts}}\right]^a \times \left[\frac{\text{Present Lpw}}{\text{Lpw Desired}}\right]^b$$

$$\text{New Wire Length} = \text{Old Wire Length} \left[\frac{\text{Watts Desired}}{\text{Present Watts}}\right]^c \times \left[\frac{\text{Present Lpw}}{\text{Lpw Desired}}\right]^d$$

2. Select proper a,b, c & d exponents from Section 2.3.3.
3. Divide Old Wire Size by New Wire Size; this is the change factor (CF).
4. Determine Old Pitch Factor A or B from Table VII and multiply by the change factor (CF). The product will be the new pitch factor A or B.
5. Determine the Pitch % for new pitch factor from Table VII. This will be the new coil winding Pitch % with original wire size.

2.5 FILAMENT CORRECTION TECHNIQUE (CONTD.)

6. Calculate new wire length from above equation and multiply by (CF) from Step 3. The product will be the corrected wire length to use original wire size.

7. Adjust filament manufacturing data to reflect new winding pitch and wire length.

8. Make new filaments and test in lamps.

The life of an incandescent lamp depends on coil temperature, wire size, coil geometry, gas fill or vacuum and many other variables. However, for a given lamp the life will vary directly with filament mass such that the weight of filament at lamp failure is a % of original weight of filament. In other words, a certain amount of tungsten evaporates from the filament before failure.

$$\text{Filament mass} = \frac{\pi d^2}{4} \times L$$

and for constant R at constant Lpw a change in wire weight requires an equal change in wire length. Therefore:

$$+ 1\%\ Ww = +2.01\%\ \text{Life}$$

or life varies with Ww^2 for a given lamp and filament design. The procedure for designing filaments allow some rough "Rules of Thumb" for gas-filled and vacuum lamps.

+ 1% wire wgt. = + 0.80% Watts, + 0.80% lpw

+ 1% wire length = - 0.55% Watts, - 1.80% lpw

By simultaneous equations, the above data can be converted to equations for constant watts or constant lpw.

2.5 FILAMENT CORRECTION TECHNIQUE - (CONTD.)

Constant Watts

Vacuum Lamps or Gas-Filled Lamps

+ 1% LPW = -0.55% Wire Weight, - 0.80% Wire Length

Constant Lpw

Vacuum Lamps or Gas-Filled Lamps

+ 1% Watts = +1.80% Wire Weight, + 0.80% Wire Length

2.6 LAMP LIFE AS A FUNCTION OF LAMP CURRENT

The life of a gas-filled incandescent lamp including halogen lamps is controlled by three major factors:

1. Filament Wire Temperature
2. Filament Wire Mass
3. The Environment Within The Bulb

The first factor is a function of LPW (efficiency). The second factor is a function of lamp current, LPW and pitch. Current is the major influence. The third factor is a function of the lamp manufacturing process and materials. On normal life test, nearly all short life failures are due to a contaminated burning environment. The filament mass controls average life vs. average LPW, and filament mass is selected to optimum for the lamp current and increases with increasing lamp current. It is for this reason that low volt lamps are superior in life to high volt lamps of the same wattage.

The following formulas can predict approximate LPW vs LIFE as a function of lamp current for a number of mount types and fill.

2.6 LAMP LIFE AS A FUNCTION OF LAMP CURRENT (CONTD.)

The type of mount and gas fill or vacuum is dictated by lamp current, coil geometry, sag, number of supports, etc. CC-8 mounts are most efficient in gas-filled lamps. Low current lamps (below .2 amps) are usually vacuum lamps with single coils.

CC-8 (With Center Support) Gas-Filled Lamps

750 Hour $LPW = 18\ I^{.25}$

CC-9 or CC-6 Gas-Filled Lamps

1000 Hour $LPW = 16.498\ I^{.254}$

C-9 Gas-Filled Lamps

1000 Hour $Lpw = 15.54\ I^{.32}$

C-9 Vacuum Lamps

1000 Hour $Lpw = 11.36\ I^{.157}$

The LPW values calculated by the above formulas are good to about ± 3% of actual and can be used to design filaments for a particular life where Lpw is not specified. These formulas are for A-line or GLS types only.

The Lpw at lives other than those indicated can be calculated from data in Section 1.1 Chapter I.

$$\left[\frac{\text{Old Life}}{\text{New Life}}\right]^{\frac{1}{b}} = \left[\frac{\text{New Lpw}}{\text{Old Lpw}}\right]$$

Note: Use b exponent based on Old Lpw.

2.7 FILAMENT WIRE

The only material of interest for incandescent lamp filaments is tungsten.

TABLE VIII

TUNGSTEN PHYSICAL PROPERTIES

Atomic number 74

Atomic weight 183.85

Isotopes 180,182,183,
184,186

Atomic volume, cc/g-mole..............9.53

Atomic valence........................6

Crystal system........................b.c.c.

Interatomic distance (25°C) A.........3.158

Closest approach of atoms A...........2.734

Density (20°C) g/cc..................
- Theoretical.........................19.17
- Presintered at approx. 1200°C.......10-12
- Sintered at approx. 3000°C..........16-18
- Swaged..............................18-19
- Drawn...............................19-19.3

Melting point, °C.....................approx. 3400
°F.....................approx. 6100

Boiling point, °C.....................approx. 5900

Linear thermal coefficient of expansion
- at 20°C.............................4.4×10^{-6}
- 100°C...............................4.5×10^{-6}
- 500°C...............................4.6×10^{-6}
- 1000°C..............................4.6×10^{-6}
- 2000°C..............................5.4×10^{-6}
- 3000°C..............................6.6×10^{-6}

Mean coefficient of thermal expansion
- 0-500°C.............................4.6×10^{-6}

Thermal conductivity, cal/cm²/cm/sec/°C
- at 20°C.............................0.40
- 500°C...............................0.29
- 1000°C..............................0.27
- 2000°C..............................0.25

Specific heat, cal/g/°C
- at 20°C.............................0.033
- 1000°C..............................0.041
- 2000°C..............................0.047

Heat of fusion, cal/g.................44

Vapor pressure, atmospheres
- at 2500°C...........................5×10^{-6}
- 3940°C..............................1×10^{-3}
- 4400°C..............................1×10^{-2}
- 5080°C..............................1×10^{-1}
- 5650°C..............................5×10^{-1}

Rate of evaporation, g/cm² sec
- at 2500°C...........................7×10^{-8}
- 3000°C..............................2.5×10^{-5}

Heat of vaporization, cal/g...........approx. 1150

Entrophy (25°C), cal/mole, °C
- Condensed phase 8
- Gaseous phase 41.5

Enthalpy (25°C) cal/g 1102

Electrical resistivity, microhm-cm
- at 20°C 5.5
- 1000°C 33
- 2000°C 67
- 3000°C 103

Temperature coefficient of electrical resistivity per °C
- 0-170°C .... 5.1×10^{-3}

Electron work function, eV 4.56

Ionization voltage, v 8.1

Electron emission, mA/cm²
- at 1000°C .... $3.2 \times 10^{-[illegible]}$
- 2000°C .... $3 \times 10^{-[illegible]}$
- 3000°C 84

Total radiation, watt/cm²
- at 800°K 0.3
- 1400°K 4.0

Velocity of sound, m/sec .... approx. 4300

Young's modulus of elasticity, kg/mm² approx. 40,000
psi .. approx. 60×10^{6}

Modulus of torsion, kg/cm²........... 1.45×10^{6}
psi .... 24×10^{6}

Modulus of rigidity, psi .... 21.5×10^{6}

Tensile strength at 20°C	kg/mm²	psi
Sinterec compact	13	18,500
Swaged rod	35-105	50,000-150,000
Drawn wire, 1 mm	180	286,000
Drawn wire, 0.2 mm	250	356,000
Drawn wire, 0.1 mm	300	427,000
Drawn wire, 0.02 mm	400-415	570,000-590,000
Recrystalized wire	110	157,000

Tensile strength at elevated temps., kg/mm², 0.6 mm wire
- at 400 C 120-160
- 800 C 80-100
- 1200 C............................. 40-60
- 1800 C............................. 10-30

Elastic limit	kg/mm²	psi
Annealed wire, 0.5.1 mm ...	72-83	$1.0\text{-}1.2 \times 10^{5}$
Unannealed wire, 0.5.1 mm...	150	2.13×10^{5}

Poisson's ratio (for single crystal). 0.284

Vickers hardness
- Sintered bar 225
- Swaged to 5 mm 407
- Reheated at 2700°C 392
- Swaged to 3.5 mm 474
- Swaged to 1.8 mm 488

2.7 FILAMENT WIRE

Pure tungsten is doped with various materials to make lamp wire. There are esentially two categories of lamp wire -- sag and non-sag (NS) lamp wire.

Types of Tungsten Wire

Sylvania manufactures wire having the following descriptions:

NS	is the Sylvania designation for non-sag tungsten wire for filaments and supports in fluorescent and incandescent lamps, electronic-tube grids and heaters, and electric furnace elements. It is available in the broadest range of standard processes, and has the widest variety of applications.
VM	is the Sylvania designation for tungsten wire furnished in either stranded or single-strand form that has been processed specifically for vacuum-metallizing applications. (Refer to technical information bulletin "Tungsten Strand for Vacuum Metallizing.")
TH	is the Sylvania designation for tungsten wire containing 0.75% to 1.1% thoria. Its principal use is for power-tube filaments and for vibration service in some types of incandescent lamps.
RW	is the Sylvania designation for tungsten-rhenium wire. (Refer to technical bulletin on Sylvania Tungsten-3% Rhenium Wire.)
AK	is the Sylvania designation for low Ni, Fe, and Ci. non-sag wire for filaments in GLS and halogen lamps of some types.

Standard Processes Non-Sag Tungsten Wire

NS-10	Designates as drawn wire, which retains the black finish from the graphite drawing lubricant. The wire is unstraightened and has high tensile strength. NS-10 is generally used for coils for incandescent and fluorescent lamps.
NS-20	Designates NS-10 wire which has been straightened but not cleaned.

2.7 FILAMENT WIRE (CONTD.)

NS-30 Designates NS-10 wire which has been chemically cleaned but not straightened.

NS-50 Designates tungsten wire which has been cleaned, straightened and annealed in a reducing atmosphere. It is generally used in electronic-tube grid and heater applications where optimum straightness and low tensile strength are required.

NS-55 Designates tungsten wire which has been chemically cleaned, straightened and stress-relieved in a reducing atmosphere. NS-55 wire has good straightness and intermediate tensile properties, finding broad usage wherever a cleaned and straightened tungsten wire is required. Generally it is used for electronic-tube grids and heaters and for lamp coils, but it serves other applications when a cleaned and straightened tungsten wire is needed.

NS-60 Designates tungsten wire which has been partially straightened under heat and tension, and chemically cleaned. NS-60 retains the high tensile strength of the as-drawn wire.

NS-80 Designates an unstraightened, electropolished wire with a high tensile strength. It is generally used in sizes below diamond-die drawing range and may be used in larger sizes where the very smooth electropolished surface is desired.

NS-85 Designates an electropolished wire with a low tensile strength, which has been straightened with heat in a reducing atmosphere. Straightness and tensile strength are comparable to those of NS-50.

NS-86 Designates an electropolished wire having intermediate tensile strength and straightness. Tensile strength and straightness are comparable to those of NS-55.

NS wire is used for all A-line GLS lamps.

TH wire is used in miniature automative vibration service lamps.

RW wire is used in appliance lamps, telephone lamps, long-life sub-miniature lamps, etc. RW filament lamps are usually vacuum lamps.

AK wire is used for some Halogen lamp types.

NS-87 Designates a partially straightened electropolished wire with high tensile strength.
Straightness and tensile strength are comparable to those of NS-60. NS-87 wire is recommended for electron-tube grids at sizes 0.5 mil and below, where a high tensile strength and a very smooth finish are required for efficient operation of automatic grid-winding machines.

THORIATED TUNGSTEN WIRE

TH-10 Designates black, as-drawn wire containing thoria.

TH-20 Designates TH-10 wire which has been straightened but not cleaned.

TH-30 Designates TH-10 wire which has been cleaned but not straightened.

TH-55 Designates TH-10 wire which has been chemically cleaned and straightened.

TH-60 Designates TH-10 wire which has been partially straightened under heat and tension, and chemically cleaned. TH-60 retains the high strength of as-drawn wire.

Non-Sag Wires

Process	Surface Finish	Tensile Strength	Straightness	Available Size Range
NS-10	Black	High	1	0.17 mg/200mm to 100 mils (2540 μM)
NS-20	Black	High	2	0.45 mg/200mm to 100 mils (2540 μM)
NS-30	Clean	High	1	0.45 mg/200mm to 100 mils (2540 μM)
NS-50	Clean	Low	4	0.45 to 50 mg/200mm
NS-55	Clean	*Intermediate	3	0.45 mg/200mm to 85 mils (2519 μM)
NS-60	Clean	High	2	0.45 to 12 mg/200mm
NS-80	Polished	High	1	0.04 mg/200mm to 10 mils (254 μM)
NS-85	Polished	Low	4	0.45 to 50 mg/200mm
NS-86	Polished	Intermediate	3	0.45 mg/200mm to 10 mils (254 μM)
NS-87	Polished	High	2	0.17 to 68 mg/200mm

THORIATED WIRES

Process	Surface Finish	Tensile Strength	Straightness	Available Size Range
TH-10	Black	High	1	1.25 mg/200mm to 40 mils (1016 μM)
TH-20	Black	High	2	1.25 mg/200mm to 40 mils (1016 μM)
TH-30	Clean	High	1	1.25 mg/200mm to 40 mils (1016 μM)
TH-55	Clean	Intermediate	3	1.25 mg/200mm to 40 mils (1016 μM)
TH-60	Clean	High	2	1.25 mg/200mm to 40 mils (1016 μM)

Straightness
1 = unstraightened
2 = partially straightened
3 = intermediate straightness
4 = best straightness

MEASUREMENT OF WIRE SIZE AND TOLERANCE

Wire sizes 20 mils (508μM) and larger are expressed in mils (thousandths of inches) or mm. Wire sizes below 20 mils are expressed in milligrams per 200 millimeters (mg/200 mm).

The relationship of milligram weight to diameter in mils can be shown as:

For NS wires: $$\text{mg/200 mm} = 1.943 \times (\text{diameter in mils})^2 = 1.943 \times \left[\frac{\text{diameter in micron meters}}{25.4}\right]^2$$

For 1% TH wires: $$\text{mg/200 mm} = \mathbf{1.905} \times (\text{diameter in mils})^2 = \mathbf{1.905} \times \left[\frac{\text{diameter in micron meters}}{25.4}\right]^2$$

Calculated milligram weights are rounded off by Sylvania to a value consistent with the sensitivity of weighing (usually to the nearest 0.01 mg).

Wire tolerances are based on the center size and are expressed as the center size plus or minus milligram/200mm, percent of milligram weight, or percent of diameter as outlined in the following table:

Wire Size Range	Tolerance Expressed As	Standard Tolerance	Other Available Tolerances
0.08 mg/200mm to 0.67 mg/200mm	mg/200mm	Varies with center size.	±0.03, ±0.025, ±0.02, ±0.015, ±0.01 ±0.005mg/200mm
0.68 mg/200mm to 19.9 mils (505μ M)	percent of milligram weight	±3%	±2½%, ±2%, ±1½%, ±1% ± ½%
20 mils (508μM) and larger	percent of diameter	±1½%	±1¼%, ±1%, ±3/4%

Different lamp wire manufacturers have other symbols for wire types:

GTE Sylvania	General Electric
NS	218
NS-55	218 CS
TH	NF
TH-10	NFB

In the as drawn condition, tungsten is fibrous and very strong and ductile. When heated to lamp operating temperature, the wire recrystallizes. The dopants in NS wire cause the crystals to grow faster along the wire than across the diameter. The result is interlocking crystals that prevent crystal slippage (sag or offset). The dopants in TH wire delay or prevent large crystals from growing, the result is a sag but non-brittle wire for lamps subject to shock and vibration. RW wire dopants also delay recrystallization and result in a sag wire for use in special lamps.

The quality of the lamp wire is critical. The specification normally will indicate the material to be used by manufacturer's code or codes, e.g. NS-10. The material may be cleaned, etched, polished or as-drawn material. Special tensile and elongation characteristics may be required. The wire has important size and weight tolerances. The wire's camber or curliness may vary. Each of the variations in the starting material requires significant process adjustment. Very few filaments are made using straight wire materials. Some large electronic devices use folded wire heaters.

2.7 FILAMENT WIRE (CONTD.)

Today, incandescent lamp filaments are single or double helix type filaments, normally called single-coil and coiled-coil filaments. The coiling is done on a mandrel which is later removed.

Contaminants are a major problem.

Tungsten contamination results in:

1. Brittleness, due to the reduced ductility of the contaminated surface and consequent cracking of the tungsten due to its notch sensitivity.
2. Bulb Wall Darkening due to the higher evaporation rates of the contaminants.
3. Objectionable Sag due to an interstitial such as carbon, and the resultant tungsten carbide dispersed in the grain boundaries and within the grains.

Nickel, iron and moly are the most common contaminants in filament and cathode manufacture. All three of these elements are substitutional in nature; that is, they are diffused into the tungsten lattice by substitution. The iron and nickel are incompatible with the tungsten, and form brittle second phases and intermetallics, which show up as small, equiax grains, the depth of which depend on the temperature and concentration of the contaminants. Moly is compatible with tungsten, does not form second phases, does not change the structure of the tungsten wire, and is usually manifest as bulb wall darkening when the filament is burned.

2.7 FILAMENT WIRE - (CONTD.)

Iron Contamination

Typical problems of iron contamination are brittle coils at inspection after mandrel dissolving. This type of contamination is usually accomplished by either too high a temperature at annealing the coil on steel mandrel, or by sintering with incomplete mandrel dissolving. Another usual problem of iron contamination is "splintering" of the tungsten wire where it was in contact with an iron mandrel during annealing.

Iron contamination of filaments intended for tungsten halogen lamp use is much more serious because iron ties up the halogen closing in relatively non-volatile compounds, resulting in early lamp blackening due to insufficient halogen.

Molybdenum Contamination

Molybdenum contamination of a tungsten filament can occur readily under certain conditions. Molybdenum is usually present in tungsten wire as a few parts per million. Usually if this value is below 50.0 PPM no difficulty will be encountered. Many filaments are wound on molybdenum mandrels and then strain relieved by heating at a temperature of about 1550°C for as much as ten minutes. Filament wire having a high ratio of surface area to mass will pick up considerable molybdenum at this temperature through a diffusion process. For this reason molybdenum supports are not used in high temperature filament designs, being replaced by ones of tungsten. In general, filament wire below 5.0 mgs/200 mm is not subjected to such high temperature treatments. More often steel mandrels are used for these sizes and the temperature for strain relieving maintained below 1100°C.

2.7 MOLYBDENUM CONTAMINATION (CONTD.)

Barrier coatings have been developed to reduce contamination of the filament by the mandrel. It may be noted that contamination is much more likely to take place where many crystal boundaries exist as in the drawn condition.

When the moly mandrel is not properly cleaned the central core of the mandrel will dissolve from the cut ends of the coil, leaving the dirty surface of the original moly mandrel intact. This condition is known as mandrel shell. Only the surface of the mandrel - the mandrel shell - remains. (This mandrel shell is so thin that it is translucent. This condition can usually be traced to a leaking cooling chamber in a sintering furnace.)

CARBON CONTAMINATION

Most everything that tungsten comes in contact with may contain or have a coating containing carbon on it. Once these carbon containing materials, e.g., graphite, oils, greases, fibers, etc., react with the heated tungsten or molybdenum, complicated chemical changes take place. Carbides are first formed embrittling the filament and filament supports of the lamp.

(1) $W + C = WC$ M.P. $3140^{o}C \pm 50^{o}C$

(2) $2W + C = W2C$ M.P. $3130^{o}C \pm 50^{o}C$

(3) $2Mo + C = Mo2C$ M.P. $2690^{o}C \pm 20^{o}C$

(4) $Mo + C = MoC$ M.P. $2700^{o}C$

When areas of a tungsten filament become carburized, the melting point is reduced by about $300^{o}C$, leading to early failures

2.7 CARBON CONTAMINATION - (CONTD.)

at the affected points. The higher vapor pressures of the carbides contribute to early blackening of the bulbs. The microstructure of tungsten is radically affected by carbon which thus detrimentally changes the sag characteristics of the filament.

Tungsten carbide can be decarburized by heating in a wet hydrogen atmosphere for extended periods. Time depends upon amount of carburization.

2.8 FILAMENT MANUFACTURING

Filament coiling is done by winding the filament wire on a mandrel, which is subsequently removed either by dissolving, as for continuous winding process and coiled coil, or by mechanical extraction, as for the automatic coiling process. Therefore, two main constituents for coiling of filaments are the filament wire and the mandrels used.

To manufacture a single coil incandescent lamp filament, specific data is required.

Mount Type Filament Designation

Filament Wire Type

Filament Wire Size and Tolerance

Non-Sag (NS) Wire $$mg/200 = 1.943 \left[\frac{\text{wire diameter in } \mu M}{25.4}\right]^2$$

Thoriated (TH) Wire $$mg/200 = 1.905 \left[\frac{\text{wire diameter in } \mu M}{25.4}\right]^2$$

2.8 FILAMENT MANUFACTURING (CONTD.)

Mandrel Wire Type

Mandrel Wire Size and Tolerance

Moly Wire mg/200 = 1.029 (wire diameter in mils)^2

Steel Wire mg/200 = .792 (wire diameter in mils)^2

Turns per inch (after coiling is completed) or turns per mm

Total turns per filament

Leg length if any

If coiled coil, additional data is required

Pin or second mandrel size in mils or microns

Secondary coiling TPI or TP mm

Secondary coiling turns per section (TPS)

Leg Length each end

NOTE: In the United States, diameters are in mils and length in millimeters.

In Europe, diameters are in μM or millimeters and length in millimeters.

2.8.1 Coil Winding Equipment

Different types of filaments require different types of coil winding equipment. In general, there are three types of coils:

A. Leg type single coils or leg type coiled coils.

B. Continuous coils to be used as single coils or to be used as primary winding for a coiled coil filament.

C. Special coils both single coil and coiled coil even triple coil. These coils require special equipment and hand working.

2.8.1 COIL WINDING EQUIPMENT - (CONTD.)

Basically, there are five types of coil winding equipment for high production A-line lamps.

I. S81 Coil Winder

The S81 Coil Winder makes continuous coiling. The filament wire is wrapped around the mandrel. The turns per inch (TPI) are controlled by the rotational speed of the head and the linear speed of the mandrel. The S81 is used to make either single coils or primary coiling for coiled coil filaments.

II. Syl-Coil Coil Winder

The Syl-Coil Coil Winder is used for the same purpose as the S81 Machines. It runs faster and puts less stress on the filament wire.

III. 4G Coil Winder

The 4G Machine is similar to the S81 except that the mandrel travel speed can be altered such that a skip space coil is wound. The result is a leg type coil but the leg is not straight. The leg is really one or more open pitch turns. A special machine called the Electronic 4G has the ability to stop the winding head and advance the mandrel and then start up again. This unit can make leg type coils with nearly straight legs. To obtain the individual leg coils, the coiling is cut in the middle of the skip space.

2.8.1 COIL WINDING EQUIPMENT - (CONTD.)

IV. Winders With Retractable Mandrel

A. C173 Coil Winder

The C173 Coil Winder makes leg type single coils or leg type coiled coils. The C173 is unique in that it has a retractable mandrel. In operation, the wire or coiling is held by the head clamp and wound around a steel mandrel. When the desired number of turns are completed, the head rotation stops and wire guide continues back to make rear leg of coil. A cutter then comes in and cuts filament wire and end of rear leg. The mandrel is then retracted and the completed coil is dropped into a tray.

The C173 Coil Winder has some limitations:

Mandrel or Pin	254 μm (10 mils) min. diameter
Number of Turns	100 turns maximum

B. A similar coil winder called an HS152 is used to make leg type coils for miniature lamps. The major difference is that before the mandrel is retracted, a coil transfer device holds the coil and instead of dropping the finished coil, the coil is transferred directly to the lead wire clamps. Wire used on the HS152 equipment is always clean because the coil goes directly into a lamp with no further treatment.

2.8.1 <u>COIL WINDING EQUIPMENT (CONTD.)</u>

C. There is also a G173 Machine. The G173 unit has the ability to heat wire being wound on mandrel and to form legs to special shapes. There is less twist put in filament wire on a G173 than on a C173 or HS152 because the wire is fed perpendicular to mandrel instead of parallel to mandrel. The G 173 also has an adjustable head stop so that the coil legs can be lined up with each other.

V. <u>S & H Coil Winder</u>

The S & H Coil Winder is used for special shapes for projection lamps, etc. The S and H Machine normally makes a leg type coil where the legs are perpendicular to coil body "U" shaped coil. The S and H Machines can be fitted with a variety of special tools for unique filament shapes.

Black wire is usually used for S81, Syl-Coil, and 4G Machines. C173 can use either black or clean but black is preferred. The HS152 always used clean and straightened wire.

The following controls should be exercised in the selection and use of filament wire:

1. The size of the filament wire must be accurately determined. Wrong size wire will give coils of incorrect wattage and efficiency ratings.

2. The wire should have a smooth, round contour. Wire with poor contour is difficult to coil at uniform pitch.

2.8.1 COIL WINDING - (CONTD.)

3. Wire with abnormal point-to-point variations in resistance may affect rating and should not be used.

4. Split wire, or wire which tends to split or sliver during coiling, may cause low efficiency and short life. Wire lots showing these tendencies should be rejected.

5. Brittle wire is very undesirable. It will break frequently during coiling and is likely to produce fragile coils.

6. Wire should not be too soft. Soft wire will appear to function well on the coiling machines but tends to stretch during coiling causing low and non-uniform ratings and may also sag in high temperature lamps.

7. The tensile strength of the filament wire should be uniform and should be chosen with due consideration being given to such factors as pitch and mandrel ratios, recoil, and actual limitations of the particular coiling machine.

2.8.2 WIRE TENSILE STRENGTH VS. COILING TENSION

The tensile strength of filament wire is, to a certain extent, a measure of its working qualities and is therefore very important. Usually, wire with low tensile strength has a low elastic limit but will withstand considerable additional tension and stretch before breaking. On the other hand, wire with high tensile strength has a high elastic limit but will not stand much additional tension or stretch before breaking.

Experience indicates that best coiling results will usually be obtained if the tension on the wire at the mandrel during coiling

2.8.2 WIRE TENSILE STRENGTH VS. COILING TENSION (CONTD.)

is just above its elastic limit. If the tension is below this point, there is too much tendency for the turns to unwind when the wire is cut after coiling. This affects lamp rating and changes the physical dimensions as well as the leg positioning of the finished coils. If the tension is too high, there is too much stretch and possible breakage of the wire during cooling. Abnormal stretch reduces the diameter of the wire and seriously affects lamp rating.

In some cases, the desired working characteristics may be attained by applying heat to the wire during cooling.

Ordinarily, the larger the wire diameter, the lower should be the inherent tensile strength per unit cross-sectional area of the wire. This is because, as wire diameters increase, it becomes difficult to apply sufficient tension during coiling to exceed the elastic limit of the wire and thus prevent an excessive amount of recoil. Conversely, as wire diameters decrease, it becomes difficult to apply low enough tensions to prevent an excessive amount of stretch.

The particular mandrel and pitch ratios of certain coils are primarily responsible for the need to specify tensile strength. These ratios are found to be necessary in order to obtain the concentrated light source dimensions, coiling and mounting machine limitations.

2.8.2 WIRE TENSILE STRENGTH VS. COILING TENSION - (CONTD.)

Type of Tungsten Wire

The types of tungsten wire available are described in Section 2.7.

The Effect of Carbon on the Microstructure of Tungsten

The presence of carbon has harmful effects on the structure of tungsten, and therefore great care should be exercised to insure that tungsten filaments are as free from carbon as possible. Tungsten filaments contaminated with carbon, distort and sag when they are operated at high temperatures and are extremely brittle at room temperature. In the process of manufacturing of coils and finished lamps, there are occasions where carbon may contaminate the tungsten: In the drawing of the wire, aquadag (a form of carbon) is used as a lubricant; In the manufacture of coils, oil and grease, either intentionally or inadvertently, may get on the tungsten; In the manufacture of lamps, carbon in the form of oil vapor may be introduced.

Carbon is only one of those undesired impurities that have harmful effects on the structure of tungsten. Other impurities include oxygen, nickel, iron and molybdenum which have effects similar to those of the interstitial atoms of carbon. Small concentrations will increase the transition temperature of tungsten filaments.

One characteristic of tungsten is the narrow temperature range over which its properties change from ductile to brittle characteristics. This narrow temperature range is the so-called low temperature brittleness point or transition temperature brittleness point or transition temperature region. The transition temperature gives an index of the ductility of tungsten filaments, a low transition temperature being desirable.

2.9 MANDRELS

Mandrel materials, useful in filament coiling or forming, are iron, steel and molybdenum. They may be used as cleaned, as drawn, coated, e.g. copper on steel. Generally, the form is round, as in wire; however, rectangular shapes are used for special filament shapes such as the C-Bar 6 type. The exact control of size is important to match the size of filament wire specified. The mandrel material must also have controlled elongation and expansion characteristics; otherwise, the filament specification cannot be met. Although most mandrels are removed from the primary coiling chemically, secondary coiling is sometimes done on a retractable mandrel.

Choice of mandrel material depends on mandrel size and heat treatment of the coils on mandrel.

When very fine mandrel wire is required, (less than 60μM), steel becomes too weak and molybdenum wire must be used. When coils on mandrel are to be treated at temperatures over 1200°C, it is essential to use Mo-mandrel as at these high temperatures diffusion of iron into tungsten causes brittle coils. At lower temperatures steel can be used.

Treatment of coils on mandrel at temperatures over 1200°C is necessary when manufacturing coiled coils and in cases where

2.9 MANDRELS (CONTD.)

length differences in single coils must be smaller than ± 0.5 mm.

2.9.1 Selection and Care of Mandrels

The following controls should be used in the selection and care of mandrels for C173 and HS152 Coil Winders.

1. The diameter of the mandrel affects filament length and consequently must be accurately determined.
2. The mandrel should be round, since out-of-roundness affects filament length and promotes coil distortion.
3. The surface of the mandrel should be free of any imperfections which might score or otherwise damage the coil. Rusting (of steel wire) should be guarded against by proper storage before use. Mandrels used for automatic coiling processes require a bright smooth finish so the coils will not bind on stripping. Such mandrels may be polished by wiping lightly with crocus cloth, but care must be taken not to change the diameter.
4. The mandrel should be of correct hardness to render it best suitable for its particular application. Mandrels used for automatic coiling processes should be hard enough to prevent grooving or excessive wear, but not so brittle as to cause frequent breakage on the machine.

2.9.2 EFFECT OF FILAMENT WIRE SIZE AND MANDREL SIZE TOLERANCES

Lamp filament wire is usually purchased to a tolerance of ± 3% of wire wgt/200 mm.

2.9.2 - EFFECT OF FILAMENT WIRE SIZE AND MANDREL SIZE TOLERANCES

If not compensated for:

+ 1% wire wgt. = + 0.80% Watts, + 0.80% L.P.W.

The change in lamp rating can nearly be compensated for by a change in filament wire length:

+ 1% Filament Length = - 0.55% Watts, - 1.8% L.P.W.

This is accomplished by a change in mandrel size.

$$\text{Filament Length} = \text{Coil Length} \left(\frac{M}{d} + 1\right) \quad / P_p$$

When coil length and P_p are held constant, filament length will vary with a change in either M or d.

Since M and d are in mils or microns and wire tolerances are usually expressed in mg/200, the following relationships are needed:

Wire diameter in Mils = A (Wire wgt. in mg/200)$^{1/2}$

Wire diameter in Microns = 25.4 A (wire wgt. in mg/200)$^{1/2}$

A = .717 for N S Wire
A = .722 for TH Wire
A = 0.987 for Moly Wire
A = 1.124 for Steel Wire

Or a 3% change in moly mandrel weight equals approximately 1.5% change in filament length:

$$M_1 = 0.987 \ (\text{wire wgt.})^{1/2}$$
$$M_2 = 0.987 \ (1.03)^{1/2} \ (\text{wire wgt.})^{1/2}$$
$$M_2 = 1.014889 \ M_1$$

Or filament length is increased by approximately 1.5%.

2.9.2 EFFECT OF FILAMENT WIRE SIZE AND MANDREL SIZE TOLERANCES

The following table shows the compensation:

+ 3% wire wgt. = + 2.4% Watts, + 2.4% L.P.W.

+ 3% Mandrel wgt. = + 1.5% Filament Length

+ 1.5% Filament Length = -0.8% Watts, -2.7% L.P.W.

Net Effect = + 1.5% Watt, -0.3% L.P.W.

It can be seen that by matching wire and mandrel, the lamp readings can be controlled to a large extent.

This data is empirical because the P_p% is held constant.

2.9.3 Effect Of Coil Winding Parameter Tolerances

Wire can vary from specification within a spool. Wire can stretch during coiling which reduces wire diameter and wire weight. Wire can recoil after cutting resulting in a longer filament length. Recoil also can change T.P.I.

The resulting quantitative effects of T.P.I. changes are difficult to generalize because the reference or base line per cent pitch varies with the lamp type. For a coil having an open pitch of 185-190% changes of 5% in T.P.I. would not materially change the ratings. On the other hand, a coil having a close pitch of 140%, would be quite sensitive to T.P.I. variations, as small changes in this range produce large changes in the mutual heating effects between the turns. This increase in mutual heating effect would increase the light output and efficiency but would decrease the wattage and life.

2.9.3 EFFECT OF COIL WINDING PARAMETER TOLERANCES - (CONTD.)

Rule of Thumb Relationships

+ 1% wire wgt. = + 0.80% Watts, + 0.80% L.P.W.

+ 1% filament length = -0.55% Watts, -1.80% L.P.W.

+ 1% T.P.I. = -0.11% Watts, + 0.48% L.P.W.

+ 1% L.P.W. = -7% life

If an error made in mounting the coil is such that the lighted filament length is affected, the following relationships occur:

1% L.T.S. (Lead Tip Spacing) = -(10 - 12%) Life
+ 0.5% Current
+ 0.5% Wattage
+ (1.5 - 1.75%) L.P.W.
+ (2 - 2½%) Lumens

2.10 Annealing of Coiled Filaments

Most designs require that the filament wire be severely deformed. For instance, the wire may be coiled around a mandrel which is sometimes less than twice its diameter. In other cases the deformation is less; however, as the coiling takes place the filament wire is under a constant tension of known magnitude. Depending on such characteristics as tensile strength, temperature at coiling, speed of coiling and winding tension, filaments are made to exacting dimensions despite the deformation. During the filament forming or winding, severe mechanical stresses are introduced and these must be relieved in order that the geometry of the filament can be preserved. In order to do this strain relieving,

2.10 ANNEALING OF COILED FILAMENTS - (CONTD.)

a process known as "annealing" is required. It essentially consists of pulling the mandrel, with its filament coil in through a tube furnace whose temperature, atmosphere and process rate are closely controlled. Generally, the atmosphere is reducing rather than neutral or oxidizing. When other than clean wire and mandrel is present, water or carbon dioxide in discrete quantities is needed and is added to the gas, thereby reacting chemically to clean up carbon as the following equations denote:

$$2C + H_2O \longrightarrow 2CO + H_2$$

$$C + CO_2 \longrightarrow 2CO$$

The temperature used may vary from 1000°C to 1600°C depending on the materials involved. Processing rates also vary substantially for the same reasons.

Steel Mandrel

Cleaned Tungsten Wire

in wet hydrogen

at 1100 - 1200°C

Mo-Mandrel

Cleaned Tungsten Wire	Black Tungsten Wire
in wet hydrogen	in wet hydrogen
at 1350 - 1600°C	at 1200 - 1400°C

In the case of a coiled coil filament design, the "annealing" of the primary coiling is a requirement before the secondary coiling operation is started.

2.10 ANNEALING OF COILED FILAMENTS (CONTD.)

Again the stresses that are introduced in secondary coiling must be relieved. Singly coiled filaments are cut to required length while on the mandrel by a special cutting machine, which produces coiling of exact cut lengths. The cut pieces of coiling may be further treated in a sintering furnace for several minutes at high temperatures prior to the mandrel removal, or the mandrel may be first removed. This furnace treatment is known as "sintering". It insures mores complete stress relief and should insure removal of extraneous contamination. The process is a batch type heat treatment performed in a controlled reducing atmosphere furnace at temperatures in the range 1100 to 1675°C.

Sintering is done at various temperatures depending on coil types. The code for sintering is a letter and number combination where the letter designates a temperature and the number the time at temperature.

B-2	1180°C	for	2 minutes
B-10	1180°C	for	10 minutes
C-10	1525°C	for	10 minutes
G-10	1675°C	for	10 minutes

Sintering is usually done in dry hydrogen.

2.11 REMOVAL OF MANDRELS

Mandrels are removed chemically by dissolving in acid.

Steel

In boiling HCl (sp. g. 1.15)

Rinse with plenty of hot distilled water and dry after dipping in alcohol

Molybdenum

In mixture of 4 parts HNO_3 (sp.g. 1.25)
4 parts H_2SO_4 (sp.g. 1.85)
2 parts water

Rinse with plenty of hot distilled water and dry after dipping in alcohol.

In both cases, coils must not be kept in the dissolving agents for a longer time than is necessary for removal of the mandrel.

When dissolving Mo-mandrel, care should be taken that the reaction does not get out of hand. **Rather small quantities of coils only should be treated at one time.**

Whenever acids are used, selected materials are required for baskets, sinks, piping, etc. These materials must not be affected by the acids which might cause contamination, or removal of filament material. Rigid controls must be exercised in this process. Reaction products from the operation are **generally toxic and** obnoxious. Specially designed equipment is necessary to neutralize the spent acids and fumes.

2.12 STABILIZED FILAMENTS

Stabilized filaments are used in precise light sources for optical instruments such as projection devices and as indirect cathode heaters for power transmitting electron tubes.

The filament is placed on a tungsten form which holds it exactly as required. It is then heated at a carefully controlled rate and temperature in order to produce a fully recrystallized structure. The filament is now brittle, so careful handling and mounting are required. No stretching or distorting can be allowed. Treatment schedules vary by type. When specifications are followed little or no distortion will take place during the life of the filament and this is of utmost importance to precision optical systems and indirectly heated cathodes used in transmitter tubes. The stabilizing process can be conducted either in a high vacuum in the presence of non-reactive gas or in a reducing atmosphere. The final performance of the filament dictates the process details.

Stabilizing temperatures and times are in the order of 2450°C for one minute.

Coils stabilized in vacuum are cooled in nitrogen.

No materials other than tungsten are allowed in the stabilizing furnace.

2.13 INSPECTION OF COILED FILAMENTS

Inspection begins with checking the lot for all geometric dimensions and filament weight. Non-uniform and otherwise defective filaments are removed. Tests for fragility are performed such as stretching the coil to a predetermined length and recording breakage. Sometimes coils are bounced in an air column. Non-uniform pitch is observed by using microscopic instruments. Statistical quality control methods are used for the greater portion of the production. Some critical types require 100% inspection.

After the inspection has been completed the filaments are placed in special containers with complete identification and then removed to the shipping area where they are forwarded to the customer.

2.14 COIL SCHEDULE CARD

All coils made by Sylvania and delivered to a lamp plant have a schedule card attached. One spool of lamp wire comprises one schedule. The schedule card lists all pertinent information relating to the manufactures of that particular lot of filaments.

Figure 2.141 is a blank coil schedule card.

2.14 COIL SCHEDULE CARD

DES. LPW	SYLVANIA ELECTRIC PRODUCTS INC.								ISSUE DATE
CODE	TYPE								
SCHEDULE NUMBER	DATA LTR	FINISHED LGT.	FIRST QUANTITY	REV. QUANTITY					
GETTER NUMBER	DATE	%	FIRST WEIGHT	SECOND WEIGHT	OP. INT. DATE				
WIRE WGT.	WIRE TYPE	WIRE LOT	DATE DRAWN	METERS ISSUED	METERS USED				
MAND.	TYPE	SIZE	WEIGHT RANGE	WGT. USED	SUPPLIER LOT D. D.				
#1			/						
#2			/						
#3			/						
TFL	COIL WGT.	TOTAL WGT.	FIN. TPI CK.	PLANT	STABILIZED DATE				
S81 4G	#1 MACH.	#1 TPI	TPI CK.	OP. INT. DATE	#2 MACH.	#2 TPI	TPI CK.	OP. INT. DATE	
NO. SEG.	IND. TPF	ACT. TPF	TPF CK.	LGT. ENDS	BODY	SPACE	4G WGT.		
ANN.	FURN.	TEMPERATURE	SPEED	TENSION	OP. INT.	DATE	200 M M		
#1							THEO.	ACT.	
#2							%	OP. INT.	
C173 S. H.	# MACH.	TPS	PIN	CONTROL LIMITS /	WGT. RUN	OP. INT. DATE			
					SINTER				
CUT	# MACH.	CUT LGT.	CUT LGT.	OP. INT. DATE	1 CODE	FURN.	OP. INT. DATE		
TREAT	1	OP. INT. DATE	2	OP. INT. DATE	2 CODE	FURN.	OP. INT. DATE		
FINISH	FOLD OP. INT.	INSERT OP. INT.	MINOR NO. OP. INT.	END STR. OP. INT.					
QUALITY	OPAL INT. DATE	BAL. INT. DATE	PULL TEST OP.	BOTTLE TEST OP.					
NOTES:									

Figure 2.141

The coil schedule card is general. Only the necessary data for a particular coil is filled in by the coil manufacturing plant. Most of the terms on the card are abbreviated. The following list 2.092 explains the schedule card terms.

2.092 SCHEDULE CARD TERMS

TERM	
Code	Product numbers for ease and computer
Type	Description - watts, volts, life, etc.
Schedule Number	For customer reference
Data	Reference to specification data letter
Finished Length	Actual finished length of lot
First Quantity	Actual amount of coils
Revised Quantity	Actual amount of coils if first quantity is revised
Getter Number	Not applicable at coil plant
First Weight	Generally not used
Second Weight	Generally not used
Wire Weight	Weight of wire used
Type	Wire type - Black, clean, etc.
Wire Lot	Wire Lot, Ingot, etc.
D. Date	Wire draw date
Mand	Mandrel
Type	Mandrel type - moly, steel, etc.
Weight Range	Weight limits of mandrel
Wgt. Used	Actual weight of mandrel used
Supplier	Mandrel supplier - Sylvania, etc.
Lot	Mandrel lot identification
#1, #2, #3	Tungsten and mandrel are matched
TFL	Total tungsten per filament
Factor	For internal coil use
Coil Weight	Weight of individual coil
Total Wgt.	Total weight of all filaments
Fin. TPI	Finished turns per inch - not used in GLS
Fin. TPS	Finished turns - not used in GLS
Pull Test	Check for brittle coils
Bottle Test	Check for brittle coils - not used in GLS
No. 1 Mach.	First winding machine
No. 1 TPI	Turns per inch - first winding
No. 2 Mach.	Second winding machine - coiled coils
No. 2 TPI	Turns per inch - second winding
Ind. TPS	Turns - machine setup-gap coiler
Act. TPS	Turns - actual-gap coiler
200 MM Theo Actual, %, TPI, CK.	Used for internal control of coil weight
No. Seg.	Number of coil segments
Body	Length of coiled section
Lgt. Ends	Length of coil ends
Space	Length of gap
4G FCW Limits	Coil weight limits for gap coiler

2.092 SCHEDULE CARD TERMS (CONTD.)

TERM	EXPLANATION
#1 & 2 Furn.*	Furnace number at annealing
#1 & 2 Temp.*	Annealing temperature
#1 & 2 Speed *	Annealing speed
Cl3 No. Mach.	Number of cutting machine used
Cl3 Cut Lgt.	Actual cut length of coil
Cl73 or SH	Coiling machines used
No. Mach	Number of machine used
TPS	Turns in coil
Pin	Second coiling mandrel used
Control Limits	Weight limits - second coiling
WGT. Run	Actual weight of second coiling
Sindering	Heat treating furnace
#1 & 2 Code*	Heat treating code - temp., time
#1 & 2 Furn.*	Number of furnace used
Process Notes	For use internally at coil plant
Notes	Additional pertinent information

*#1 & 2 - In some cases the operation may be done twice.

2.15 REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

1. Incandescent Lamps by W. G. Matheson, GTE Sylvania, Inc., Danvers, Mass. 01923

2. The Collected Works of Irving Langmuir - Volume II - Pergamon Press

3. Light Sources by W. Elenbaas
Crane, Russak and Co. Inc., 52 Vanderbilt Avenue, New York, New York 10017

4. Materials of High Vacuum Technology by Werner Espe - Permagon Press, 44-01 24th Street, Long Island,City, New York 11101

5. Lamp Manufacturer's Bulletins: GTE Sylvania Inc., General Electric Company, Westinghouse, Philips

6. IES Handbook from IES Society

7. Coil Design - Parts I and II by Gage N. Aborn, Lamp Engineering Group, GTE Sylvania Inc., Loring Ave., Salem, Massachusetts 01970

8. Filament Design Manual by D. R. Dayton, G.T.E. Sylvania, Inc., Danvers, Massachusetts 01923

9. Tungsten Wire Properties
Sylvania Metallurgical Products Technical Information Bulletins
GTE Sylvania Precision Materials Group
Chemical and Metallurgical Division, Towanda,Pennsylvania 18848

10. Coil Manufacturing by F. George, Internal Reports, GTE Sylvania Inc., Exeter, N. H.

11. Life - Failure Mechanisms of Incandescent Lamps by D. R. Dayton, GTE Sylvania Inc., Danvers, Massachusetts 01923

12. The Basis of the Incandescent Lamp by Bernard Kopelman, GTE Sylvania, Inc., Danvers, Massachusetts 01923

13. Filament Design without Reference Lamp Data - Programs for T1-59 Calculators - D. R. Dayton, GTE Sylvania, Ipswich, Mass. 01938.

LEAD WIRE

3.0 Lead Wires

The primary purpose of lead wires is to carry current from a source external to the lamp, through a hermetic seal in the stem press, to the lamp filament.

Lead wires also serve as a support for the filament and on some lamp types, to anchor bridges and supports or tie wires. In addition, if getters are used, they are usually applied to the lead wires.

Lead wires vary in size, diameter, and materials depending on lamp current, lamp type and stem glass type. Leads are made in single piece, two piece, or three piece. Some special four and five piece leads are also made.

3.1 Lead Wire Nomenclature

Basic Lead Wire Parts

Inner Lead - That part of the lead wire which extends from the stem press or glass seal to the filament.

Press Lead - That part of the lead wire which is within the stem press or lead seal and makes a vacuum-tight joint with the glass.

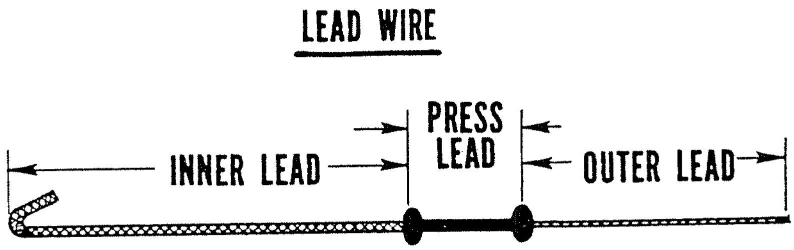
Outer Lead - That portion of the lead wire which extends from the stem press or glass seal to the lamp or tube base.

Fused Lead - A lead wire in which one part, usually the outer lead, has been designed to act as a fuse.

3.1 LEAD WIRE NOMENCLATURE--(CONTD.)

Each part is identified in the following manner: The first two digits give the diameter of the lead wire in mils (thousandths of an inch); the length is then stated in millimeters using 1, 2, or 3 digits as needed; an abbreviation next identifies the type of material; and then the shape of the end of the lead wire.

No symbol signifies that the lead is made from straight round wire.



Diameter In Mils	Length Millimeters	Material	Shape		
50	95	Ni(S)	"A" Hk	←	Inner Lead
25	5	D		←	Press Lead
40	116	Cu		←	Outer Lead

3.1.1 In Europe, the diameter of leads is expressed in millimeters. The example would be expressed as follows:

1.27 X 95 Ni(s)	"A" Hk	Inner Lead
0.64 X 5 Copper Clad		Press Lead
1.02 X 116 Cu		Outer Lead

NOTE: Dumet is called Copper Clad in Europe

3.2 MATERIAL DESIGNATION

A. The following table lists the symbols and corresponding materials now being used for the lead wires:

Symbol	Description
A	Platinum
CCFe	Copper Clad Iron (Copper Weld Wire)
CF	Chrome Iron, Alloy #446
Cu	Copper, Oxygen Free High Conductivity
Cu(NP)	Copper, Oxygen Free High Conductivity, Nickel Plated
D	Dumet, Borated - see Spec. 2A0300-7
D(L)	Dumet, Light Borated - see Spec. 2A0300-7
D(NP)	Dumet, Nickel Plated - see Spec. 2A0300-7
D(U)	Dumet, Unborated
Ev	Everdur (Silicon Bronze)
Ev(TP)	Everdur, Tin Plated
Fe	Iron
Fe(NP)	Iron, Nickel Plated
Fe(NCP)	Iron, Nickel Plated, then Copper Plated
Fn	Fernico
KUL	Kulgrid - 28% Nickel Clad Copper
Mo	Molybdenum
Mo(B)	Molybdenum, Borated
Mo(O)	Molybdenum, Oxidized
Ni	Nickel, 205 (Soft)
Ni(CP)	Nickel, 205CP (Soft), Copper Plated
Ni(S)	Nickel, 205S Degassified
NID	Nickel, 211 Manganese Alloy
NID(CP)	Nickel Manganese Alloy, Copper Plated
NiFe	Nickel Iron Alloy
NiP	RCA Iron Nickel Plated
W(HVS)	Tungsten, High Vacuum Seal
W	Tungsten, Other than High Vacuum Lead - G. E.

LEAD WIRE

Symbol	Description
W	Tungsten, other than High Vacuum Lead - Sylvania - Warren
TS-1	Iron-Flash Copper Coated
TS-1(NP)	Iron-Flash Copper Coated, Nickel Plated
ZRCU(NP)	Nickel Plated Zirconium Copper Alloy

B. Symbols following the material designation show hardness as given below:

Material	Designation	Hardness
Copper or Nickel	None	Soft and annealed
Nickel	1 HH	One hole hard or 1/4 hard
Nickel	4 HH	Four holes hard or full hard
Copper	Hd	Hard Temper

Examples of various lead wire designations and their explanations:

(1) 1659 Cu(NP)-163D-1852Cu

	Inner Lead	Press Lead	Outer Lead
Diameter	16 mil (0.41 mm)	16 mil (0.41mm)	18 mil (0.46 mm)
Length	59 mm	3 mm	52 mm
Material	Copper, Nickel Plated	Dumet Copper Clad	Copper
Type	Straight	-	-

(2) 35111Ni(S)Hk, Corr-1612D-1476NiD(CP) #2 Ann

	Inner Lead	Press Lead	Outer Lead
Diameter	35 mil (0.89 mm)	16 mil (0.41mm)	14 mil (0.36 mm)
Length	111 mm	12 mm	76 mm
Material	Nickel, Grade A Degassed	Dumet Copper Clad	Nickel Manganese Alloy, Copper Plated
Type	Hook, Corrugated and Hook Annealed	--	-

Tolerances of Weld Knots, Weld Knot Strength, Lead Straightness, and Lead Diameter and Length Tolerances.

3.3 WELD KNOT SIZES

Material	If Diameter of Press is-(Mils)	Weld Knot Shall Be No Greater Than Dia. of Larger Wire Plus
Dumet	8 to 16	13 Mils
	16 to 40	*
	8 to 40	20 Mils
Tungsten	41 to 50	30 Mils
or Moly	51 to 60	35 Mils
	Above 60	(Varies with Materials Used)

* Note: For Dumet wire larger than 16 Mils, the weld knot diameter will vary depending on both physical and chemical properties of the two materials involved.

3.4 WELD KNOT STRENGTH TEST

The foregoing test may be applied to all leads except those types using Tungsten, or Molybdenum or extremely hard wire (such as Monel, #52 Alloy, etc.). Those exceptions require a special test depending upon the material and ultimate lead requirements.

1. Grasp lead adjacent to weld knot.
2. With one hand, bend the lead sharply at the knot 45° away from the body.
3. From position in #2, bend lead 90° toward body.
4. From position in #3, bend lead 45° to original position in #1.

3.5 LEAD STRAIGHTNESS

The inner lead shall be sufficiently straight and free of burrs so that it shall drop by its own weight to within 3mm of the weld knot through a cylindrical hole gauge described as follows:

Lead Wire Sizes	Dimensions of Gauge: Length	Dimensions of Gauge: Inside Diameter of Hole
.050 Inches or Smaller	2"	.005" greater than wire diameter
.051 Inches or Larger	2"	.007" greater than wire diameter

3.6 DIAMETER AND LENGTH TOLERANCES

A. Machine Made Two or Three Part Leads:

Lead Section	Wire Diameter (Mils)	Length (mm)	Diameter Tolerance (Mils	Length Tolerance (mm)
Inner Lead	10 to 30		±1	± 1/2
	31 to 60	any	±2	± 3/4
	61 to 100		±3	± 3/4
Press Lead	10 to 20	9 or less	±0.2	± 1/4
	10 to 20	Over 9	±0.2	± 1/2
	21 to 32	9 or less	±0.5	± 1/4
	21 to 32	Over 9	±0.5	± 1/2
Outer Lead (Non Fuse)	9 to 20	Any	±1	± 1/2
	21 to 60		±2	± 3/4
Outer Lead (Fuse)	8 to 10 inclu.		0.20-0.30	
	11 to 16 inclu.	Any	0.25-0.35	
	17 to 20 inclu.		0.40-0.50	

Note: For one-part leads, the diameter tolerance for press leads given above will apply. Tolerance for total length is ± 1/2mm.

B. Hand Made Two or Three Part Leads:

Lead Section	Wire Diameter (Mils)	Length (mm)	Diameter Tolerance (Mils)	Length Tolerance (mm)
Inner Lead	10 to 30		±1	± 3/4
	31 to 60	Any	±2	± 3/4
	61 to 100		±3	± 3/4
Press Lead	10 to 20	Any	±0.2	+1, -1/2
	21 to 40		±0.5	+1, -1/2
Outer Lead	9 to 20	Any	±1	±1
	21 to 60		±2	±1

3.6 DIAMETER AND LENGTH TOLERANCES-(CONTD.)

B. Note: In case stranded wire is used on outer lead, the length tolerance is ± 2mm and diameter tolerance is ± 5 Mils. In case press lead is of Tungsten or Molybdenum, the diameter tolerance is ± 1 Mil.

3.7 INNER LEAD MATERIALS AND LAMP TYPES

Material	Typical Applications
Nickel (s)	Automotive Lamps (Stem Seal)
Copper	Vacuum Lamps
Dumet	Miniature Vacuum Lamps
Dumet (NP)	Automotive Wedge Lamps
Iron (NP)	Sealed Beam and Par Lamps
Copper (NP)	"A" Line G.L.S. Lamps

Copper is the most common material for vacuum lamps with dumet being used in many low wattage types. In gas-filled lamps, a material is needed that will remain free of oxides in close proximity to the filament. The danger from oxides is a water cycle starting from free hydrogen being present.

Nickel plated copper and nickel are common materials used on inner leads of gas-filled lamps.

Degassed nickel (NiS) is used for inner leads. Degassing (Hydrogen firing) removes carbon from the nickel. The presence of greater than .01% carbon results in brittle filament legs which will fracture easily.

Nickel plated iron inner leads have been unsuccessful on low wattage lamps except for sealed **beam** automotive lamps.

LEAD WIRE

3.8 Press Lead

Dumet (Copperclad) is the most common material for press section of leads. Dumet seals to either lime (008) or lead (001) glass. Dumet is used as a single piece lead for microminiature, subminiature, and butt seal lamps. Nickel plated dumet is used as a single piece lead for automotive wedge type lamps and wedge base flash lamps (AG1).

Dumet is not usually used in sizes less than 10 Mils or greater than 25 Mils. The length of dumet in the actual seal is not usually greater than approximately 12 mm.

The size of the dumet is a function of the lamp operating current. The following table shows the current carrying capacity of dumet seals where seal length is 5 mm.

DUMET DIA. IN MM.	DUMET DIA. IN MILS	CURRENT CAPACITY IN AMPS
.15	6	1.35
.20	8	2.33
.25	10	3.56
.30	12	5.00
.35	14	6.75
.40	16	8.70
.45	18	10.88
.50	20	13.30

Tungsten is the most common material for press section of leads for hard glass. Tungsten seals to either nonex (7720) or pyrex (7740) glass.

3.9 Outer Leads

The outer lead wire connects the press section to the base. In vacuum lamps, this is made primarily of copper. When high temperatures are encountered such as in oven lamps, nickel plating is added to prevent oxidation throughout life. Usually one of the outer leads in a gas-filled lamp is designed with a fuse to prevent violent lamp failures from an internal arc at time of failure. The type and size of the fuse requires careful consider-ation.

In Europe, copped plated iron is often used for outer leads for G.L.S. lamps. There is some flexibility in outer lead material when lamp current is low. Monel is frequently used as a fuse lead in GLS lamps in Europe.

3.10 Fuse Lead

GLS lamps are fused to prevent a sustained arc which can cause the lamp to explode by developing excessive power and heat in the lamp. The arc occurs when the filament fails and the current is carried by ionized gases instead of the filament.

The fuse must be large enough to carry the inrush current and the operating current and small enough to fail (melt) when an arc occurs. The material for the fuse must not deteriorate during the normal life and burning environment of the lamp.

The fuse is usually located in the outer lead to the center contact. Some projection lamps have the fuse inside the lamp. Splatter of metal at fuse failure is prevented by a glass sleeve over the fuse.

3.10 FUSE LEAD - (CONTD.)

When the fuse in the base fails, there is a possibility of an arc in the base. This arc can destroy the base and the lamp socket.

There are several methods used to prevent base arcs:

(a) Ballatini Fuse

The fuse section is contained in a glass tube filled with glass sand and glass balls. When the fuse fails, the arc is extinguished and not allowed to arc to the other base lead or to the base itself.

(b) Base Shell Insulation

No discharge can take place between the metal shell of the lamp base and fuse wire if the shell is covered with an insulating material on the inside. This method is not applicable to all bases.

(c) Frothy Insulation

In this case, a double base fill is necessary. The regular basing cement is applied first as a ring near the top or open end of the base.

The space below the cement and closed end of base is filled with a "Frothy Insulation". The fuse wire can melt and evaporate, but as a result, the pressure in the cells in the froth around the wire will become too high for an arc or discharge. Even if an arc should occur, because of the large number of cells between fuse wire and base shell, the arc cannot extend to the base shell.

(c) FROTHY INSULATION (CONTD.)

A material for this application consists of:

(a) Hexamethylene tetramine - 10% by Wgt.

(b) Novolak (epoxy resin) - 50% by Wgt.

(c) Dolomite (Magnesium Calcium Carbonate - 35% by Wgt.

(d) Wood Flour - 5% by Wgt.

When heated, the Novolak polymerizes under the effect of the hexamethylene tetramine into a substance similar to bakelite. During this process, water vapor, ammonia and a quantity of carbon dioxide are released which blow up the polymerising mixture to a frothy mass. Some center contact soldering problems are common.

Nearly always a small portion of this material will be extruded through openings in the lamp cap; before the contact can be soldered this surface, foam will have to be removed with hard brushes.

Not only does the evaporating metal itself cause a high vapour pressure in the cells of the froth, but this froth decomposes under influence of the high temperature so that a rather large quantity of carbon dioxide is released from the dolomite. These gaseous reaction products increase the gas pressure in the cells considerably, so that the chance of arc forming becomes even smaller.

(d) Sand

Filling the lamp base with fine sand gives good results but would be extremely difficult to handle in production. Sometimes stem tubes of critical lamps (Miners lamps) are filled with sand.

3.10 FUSE LEAD - (CONTD.)

(e) Arc Suppresent Gases

Another method to prevent base arc is to use a basing cement which generates an arc suppresent gas when heated. The usual gas is a Halogen.

3.10.1 Fuse Design

The parameter that is most useful in studying fuse characteristics is I^2t where I is the rms current and t is the burnout time. There are two main arguments for the usefulness of I^2t. First, it is an indication of the energy to melt a fuse. Second, it is a constant for a wide range of high current values. Actually the I^2t for the clearing of a fuse can be divided into two parts, namely melting and arcing. The arcing I^2t contribution is usually negligible until subcycle melting occurs. Hence the clearing I^2t and the melting I^2t can usually be equated.

$$(1) \quad I^2t = \frac{oA^2}{K}\left[\frac{cTm + L}{T_o} - c\right], \text{ and } \quad T_o >> \theta, \quad T_m > T_o$$

where
- o is the density of the fuse material,
- A is the cross-sectional area,
- c is the specific heat capacity,
- T_o is the ambient temperature,
- T_m is the melting point temperature,
- θ is the Debye temperature,
- L is latent heat of fusion, and
- K is the constant related to atomic parameters.

3.10.1 FUSE DESIGN (CONTD.)

If the radiant heat and end effect heat losses are ignored, then the heat necessary, Q_m, to melt a fuse is given as follows:

(2) $Q_m = mc\,(T_m - T_o) + mL, \quad T_m > T_o,$,

where m is the mass of the fuse,

c is the specific heat,

T_m is the melting point temperature,

T_o is the ambient temperature, and

L is the latent heat of fusion.

The source of energy for Q_m is heating. Thus,

(3) $I^2Rt = mc\,(T_m - T_o) + mL,$

where I is the rms current,

R is the average resistance, and

t is the time elapsed for melting.

Furthermore, for a fuse of uniform cross-sectional area, A, and length, l, the resistance is given as follows:

(4) $R = \rho \frac{l}{A},$

where ρ is the resistivity of the substance.

For metals in the temperature range such that,

$T_o \gg \theta$,

where θ is the Debye temperature of the metal then

(5) $\rho = KT_o$,

where K is a constant related to atomic parameters.

3.10.1 FUSE DESIGN (CONTD.)

The lower limit in temperature for which equation (1) applies is the Debye temperature, θ, and the upper limit is the melting temperature.

The Debye temperature is a characteristic of a material and it marks the point in temperature where the resistivity of a metal radically changes.

For nickel, equation (1) would apply when the ambient temperature is between the following limits:

$$183^{\circ}C < T_o < 1455^{\circ}C \quad \text{or} \quad 456^{\circ}K < T_o < 1728^{\circ}K$$

The following table lists some representative values of the Debye temperature:

TABLE I

Representative Values of θ *

Compiled P. Keesoom and N. Pearlman

Substance	°K	Substance	°K	Substance	°K
Be	1160	Fe	467	Al	418
Mg	406	Cu	445	In	109
Ca	219	Ni	456	Tl	89
La	132	Pb	275	C(Diamond)	(2000)
Ti	278	Pt	229	Si	658
Zr	270	Cu	339	Ge	366
V	273	Ag	225	Sn(Gray)	212
Nb	252	An	165	Sn(White)	189
Ta	231	Zn	308	Pb	94.5
Cr	402	Cd	300	Bi	117
Mo	425	Hg	(60-90)		
W	379				

3.10.1 <u>FUSE DESIGN - (CONTD.)</u>

Note that for a given material at a constant T_o, I^2t is independent of the fuse length ℓ, when ℓ is greater than 2.5mm and is directly proportional to the area squared, A^2. Now if A is fixed, then I^2t is inversely proportional to T_o.

It is reasonable to expect that a given lamp type will explode when the arcing power is above a certain value, and conversely the lamp will internally quench the arc when the power is below that value.

Actually there are two limits for the selection of a fuse. The lower limit is set by the I^2t value associated with the inrush current. The upper limit is the I^2t value at which the lamp explodes. The inrush I^2t was empirically found to be given as follows:

$$I^2t \simeq 60 I_o^2 \text{ in (amp}^2 \text{ X\# of cycles)},$$

where I_o is the normal operating current through the lamp. This rule of thumb was found to hold over the range of lamps tested, namely 250W to 1500W.

3.10.1 FUSE DESIGN - (CONTD.)

At the present time, it appears impossible to predict an operating pressure and percentage of fill gas which can make a wide range of lamp types stable during arcing.

If, however, the power during arcing is minimized, then the inrush limitation is adequate to select a fuse for a given lamp.

LAMP WATTAGE VERSUS FUSE SIZE

LAMP WATTAGE (120V)	FUSE SIZE
15W CA9	.009
25W CA9	.009
40W CA9F15	.009
50W R20	.009
60	.009
75	.010
100	.010
150	.012
200	.012
250	.014

3.10.2 FUSE LEAD MATERIALS

The most common material we use for fuses is known as "D" Nickel, (NiD). This is an alloy of nickel with about 4.5% Manganese which increases the electrical resistance 57%. This alloy is resistant to oxidation. The smallest diameter NiD used on lamp fuses is .008", a limit imposed by the ability to handle the small wire. Philips uses 0.16 mm monel fuses (approximately .006").

Typical fuse size and lamp types with current to blow fuse:

Diameter	Material	Typical Lamp Style	Current To Blow Fuse
.008"	NiD	40T8, 50/HV/RS	4.2 Amperes
.009"	NiD	40 through 75W/RV/A19	5.3 Amperes
.010"	NiD	100W/RV	5.9 Amperes
.010"	Cu(NP)	500W/RV	10.3 Amperes
.012"	NiD	150W and 200W/RV	7.6 Amperes
.012"	Cu(NP)	500W/RV	14.2 Amperes
.014"	NiD	300W/RV	
.018"	NiD	750 and 1000W/HV	
.020"	Cu(NP)	750 and 1000W/RV	
.025"	Ni	1500W/RV	

Monel is common in Europe for Fuse Leads.

3.11 Storage of Leads

The materials of which lead wires are made "weather" quickly during the summer months when humidity and temperatures are high. The stock should be securely wrapped in order to keep the moist air away. Good lamp making practice avoids having leads laying around the machines unwrapped and has the stock stored in areas

3.11 STORAGE OF LEADS-(CONT'D.)

of low humidity such as a "hot" room or heated cabinets. Specifications call for storage in areas at an ambient of 95° $\pm$ 5°F.

3.12 Reference for Additional In-Depth Information

1. Guide to Specification for Automatic Welded Lead-In Wires, GTE Sylvania, Inc., Precision Materials Group, Bangor, Maine

2. Lead Wire and Solder by Robert H. Dickinson GTE Sylvania, Inc., 71 Loring Ave., Salem, Mass., 01970

3. Glass-to-Metal Seals (238 pages) Dr. J. H. Partridge, Society of Glass Technology, Elmfield, Northumberland Rd., Sheffield, England (1949)

4. Handbook of Materials and Techniques for Vacuum Devices, Dr. Walter H. Kohl, Reinhold Publishing Corp., (1967)

5. Glass-Metal Seals in Glass Engineering Handbook (Chapter 5) E. B. Shand, McGraw-Hill Book Company, Inc. (1958)

6. Materials of High Vacuum Technology
   Volume I Metals and Metaloids
   Volume II Silicates (glasses)
   Volume III Auxiliary Materials
   Dr. Werner Espe, Pergamon Press - translated from German (1968)

7. Fitzergold, E. and Stewart, V., "High-Capacity Current-Limiting Fuses Today", Presented at the AIEE Fall General Meeting in October, 1958

8. Cobine, J., Gaseous Conductors, Dover Press, Chapter 9

9. Report on Fusing by E. Passmore, GTE Sylvania, Danvers, Mass., 01915

THE BULB

4.0 The Bulb Serves Two Major Functions:

1. Protects the filament by containing an inert gas or vacuum environment around the filament.

2. Transmits the luminous energy from the filament to the subject to be illuminated.

The only material suitable for incandescent lamps is glass. Bulbs are usually made from standard lime glass such as Corning Type 008. Where higher wattages, smaller bulbs, or outdoor applications are involved, low expansion glasses of the heat resistant type are required. These are the borosilicate glasses. Borosilicate glasses are also used for pressed glass parts, such as, the reflector and lens for PAR and Sealed Beam Automotive lamps. Borosilicate glasses are sometimes called Pyrex or Nonex. The term soft glass refers to the lower melting lime and lead glasses. Hard glass refers to the borosilicate and other higher temperature glasses. Hard and soft glass are explained in more detail in Section 8.0.

4.1 BULB SHAPES

The bulb shape is chosen to suit the wattage and application of the lamp. The bulb size is controlled by the permissible bulb temperatures. The higher the wattage, the larger the bulb.

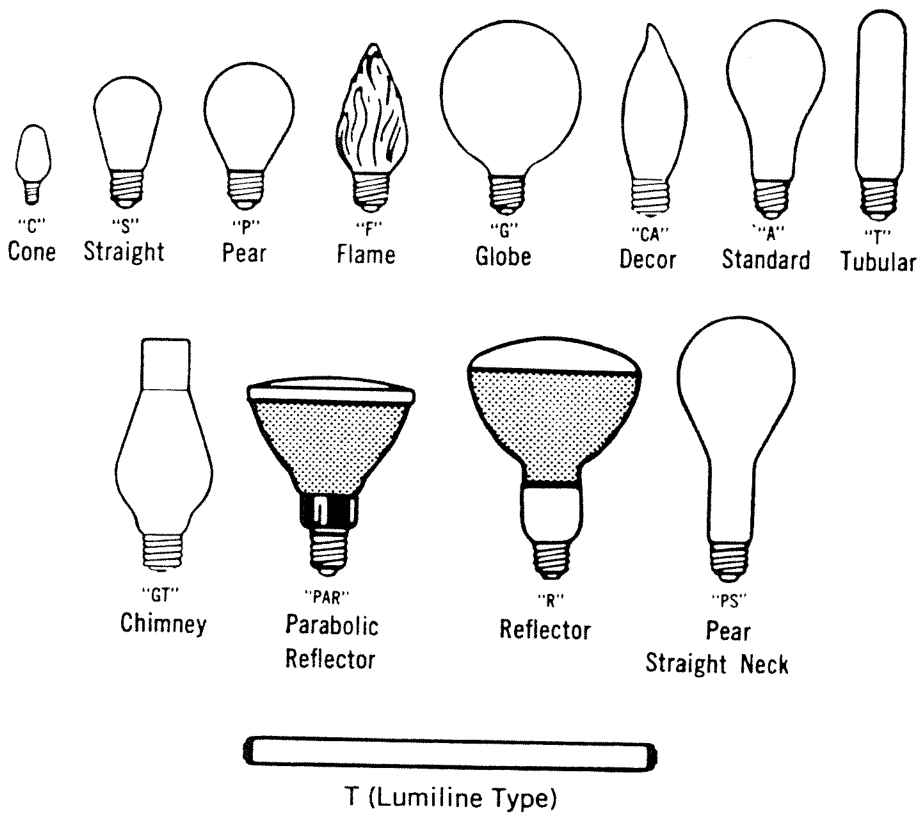
The following tables show standard bulb shapes, how the bulbs are identified, and permissible base - bulb temperatures.

Various Bulb Shapes of Incandescent Lamps

Bulb Shape	Meaning	Typical Lamps Using This Bulb
A	Standard	60 Watt A19, Inside Frost
C	Cone	7 Watt, C-7, Night Light
CA	Candle	15, 25, 40, 60 W, CA-9 Decorative
F	Flame	15 Watt, F-10, Decorative
G	Globe	40W, G-25, Decorative
GT	Globe, Tubular	60W, GT-19 Small Chimney Lamp
P	Pear	150 Watt, P-25, Locomotive Headlight
PAR	Parabolic Reflector	150 Watt, Par-38, Spot
PS	Pear, Straight Neck	500 Watt, PS-40, Clear
R	Reflector	150 Watt, R-40, Reflector
S	Straight Side	11 Watt, S-14, Sign and Decorative
T	Tubular	25 Watt, T-10, Showcase
T	Tubular (Lumiline)	40 Watt, T-8, Lumiline

Note:

The figures following the letters designate the bulb's maximum diameter in eighths of an inch. Thus, a G-30 bulb is a globe shaped lamp with a diameter 30/8 inches, or 3 3/4 inches.



Incandescent Lamp Bulb Shapes

Maximum Bare-Bulb Temperatures of Standard Incandescent Lamps*

Watts at 120 Volts	Bulb	^{o}Centigrade
25	A-19 (A-60)	43
40	A-19 (A-60)	127
60	A-19 (A-60)	124
100	A-19 (A-60)	149
150	A-23 (A-73)	138
200	A-23 (A-73)	174
300	PS-30(PS-95)	196
500	PS-35(PS-111)	212
1000	PS-52(PS-165)	249
1500	PS-52(PS-165)	266

* Bare Lamp Burning Vertically, Base Up

GTE Sylvania Company Private

THE BULB

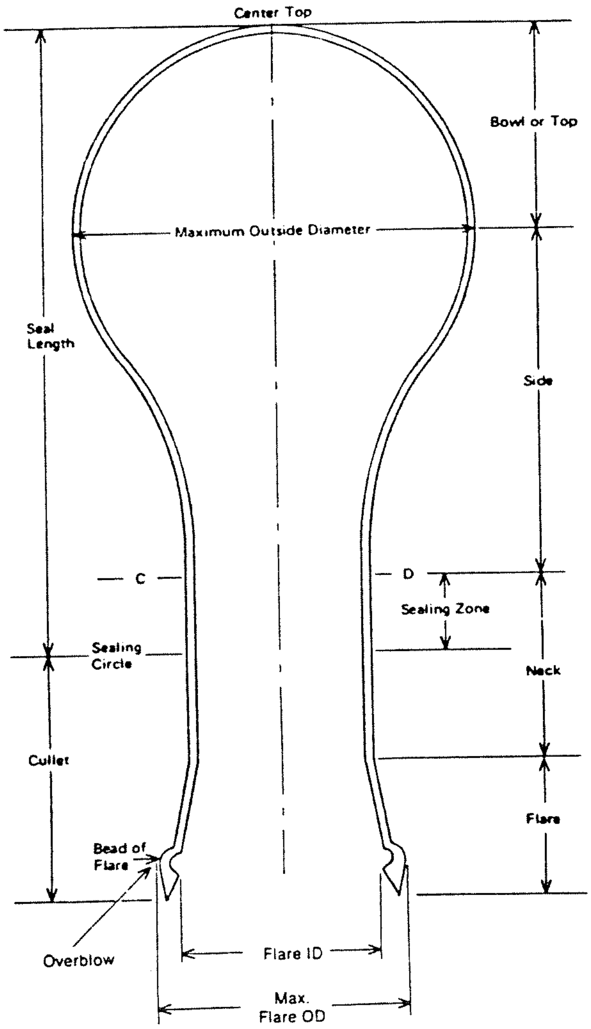
Note that "A" is indicated to mean a standard bulb. Actually "A" stands for average. In 1928, the "A" bulb was designed from a composite of the PS, P, S, and G shapes.

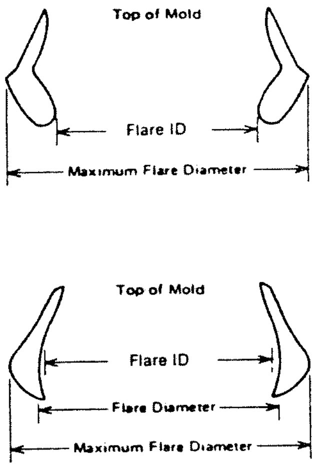
In Europe, the bulb shapes are similar but the size designations are different. The following table shows the European size and equal U.S. size:

Diameter	U.S.A.	Europe
one inch	S-8	S-25mm
1 3/4 inches	T-14	T-44mm
2 5/8 inches	A-21	A-66mm

1/8 inch = approximately 3.125mm

4.2 Bulb Nomenclature





THE BULB

Bulb Nomenclature

Top (Bowl)	- The portion of the bulb above the major diameter.
CD Line	- An arbitrary reference line at the junction of the neck and body at the end from which the bulb is blown.
Cullet	- The portion of a bulb that is cut off and discarded at the time of sealing by the lamp manufacturer.
Flare	- Refers to the enlarged portion of the neck at the open end of a bulb.
Overblow	- That segment of the flare above the portion formed by the plate as outlined on bulb drawing. This shape is not controlled.
Flare I. D.	- The inside diameter of the bulb at the flare.
Side of Bulb	- The portion between the major diameter and the CD Line.
Neck	- The portion of a bulb that lies between the CD line and the flare.
Neck Straight	- That portion of the neck having a uniform outside diameter.
Maximum Diameter	- On "T" bulbs, the junction of the upper side and top.
Measuring Position	- Vertical distance from outside center of top or dome of bulb to line where wall thickness of bulb is to be measured.
Sealing Strength	- The distance from the top of the bulb to the sealing line.
Sealing Zone	- Any portion within a seal as made by the lamp manufacturer.
Sealing Line	- The circumferential line that marks the nominal location at which the bulb is sealed off by the lamp manufacturer.

Definition of Defects

Crack	- A fissure extending through the wall of a glass article.
Check	- A fissure extending into, but not through, the wall of a glass article.

DEFINITION OF DEFECTS - (CONTD.)

Bruise	- A fissure which is usually half moon or of a similar irregular configuration and has no glass removed from the surface. It is iridescent under bright light. (Caused by impact.)
Scale	- Particles of carbon or metallic substances adhered to or imbedded in the glass. These are usually red or black.
Stone	- Undissolved or recrystallized material imbedded in the glass, generally white in color, appearing in the form of an opaque lump or flake. The size is the maximum dimension of the opaque portion.
Flare Inside Diameter	- The minimum inside diameter of the flare as measured with a plug gage.
Flare Outside Diameter	- The total distance outside diameter of the overblow and flare as measured with a ring gage.
Hang Nail	- A protruding section of glass at the crack-off position perpendicular to the axis of the bulb.
Chipped	- Depression or irregularity on glass surface caused by the flaking off of a glass particle. Chipped implies only part of the wall thickness is removed.
Stress	- Tensile or compressive forces existing within the glass. This condition can be seen or located with a Polariscope or Polarimeter.
Neck Twisted	- A bulb with indentations due to twisting in the mold.
Adhered Glass	- Small glass particles partially fused to the outside glass surface, which cannot be removed without causing a chip or a check.
Mold Ring	- A circumferential indented ring on the glass surface.
Scuff (Scratch)	- An elongated line abrasion which is not checked, as viewed in normal reflected room lighting without the use of magnification.

DEFINITION OF DEFECTS - (CONTD.)

Butterfly Top	- A pinch appearance in the top of a blown bulb that is suggestive of the shape of a butterfly.
Cord	- A narrow band of glass having a visibly different index of refraction from the surrounding glass.
Frost Cloud	- A frosted bulb with its surface having areas with non-uniform frost -- this normally takes the form of a line running axially from the flare toward the top of the bulb.
Neck Siding (Streak)	- Variation in wall thickness of the neck at the measuring position. (This is within a piece variation as opposed to piece-to-piece variations.)

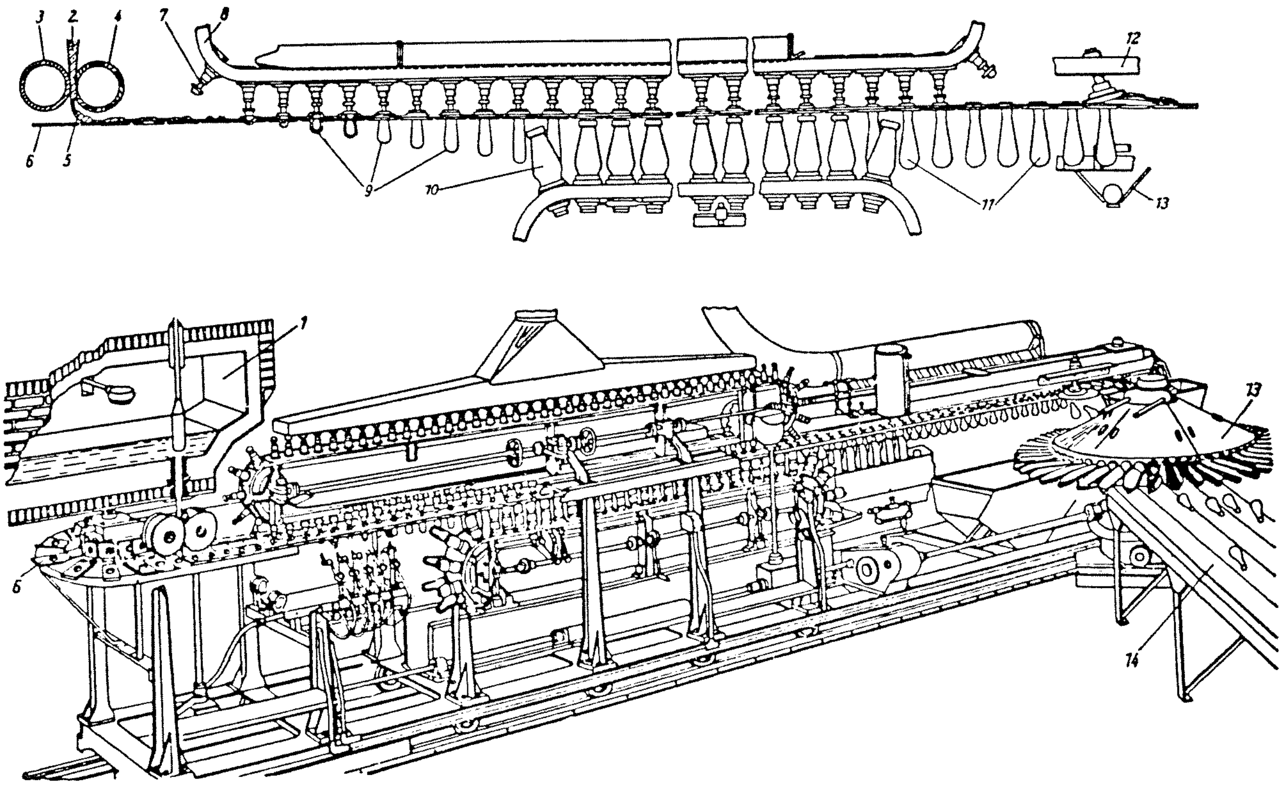
4.3 Bulb Manufacturing

Bulbs are made from glass tubing or blown on a ribbon machine. In this latter device a stream of hot glass, flowing without interruption from the orifice of a feeder, passes between two rolls. One of these rolls carries a series of circular depressions and the other is smooth. The result is a ribbon of glass about three inches wide carrying a series of bosses closely spaced along its upper surface. This ribbon bends to the horizontal direction and is carried on a continuous chain of steel plates with sharp edged orifices synchronized with the bosses of hot glass which sag through the holes. These are blown or "developed" by a series of traveling blow heads, at first with gentle puffs as the embryo bulbs sag in air and finally with more pressure after a series of paste molds, carried by a third chain below the ribbon, rise, close around the parisons and begin to rotate. This blows the glass into a thin bulb

4.3 BULB MANUFACTURING-(CONTD.)

against the spinning molds which stop spinning and open to release the bulb as soon as the glass is rigid. The bulbs continue attached to the ribbon until they are tapped off by a light blow from a hammer device and transferred to a steel mesh belt passing through an anneal lehr.

The speed of the ribbon machine varies from 300 - 2500 pieces per minute depending on the size and mass of the bulbs.

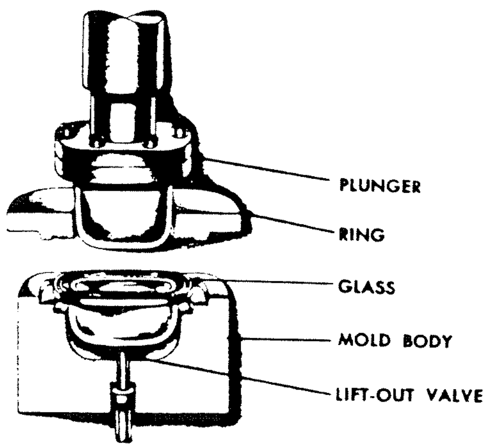


Construction of a RIBBON glass bulb machine of CORNING Glass Works. Daily output more than 1 million bulbs

1 glass furnace; *2* cord of viscous glass; *3* smooth roll; *4* profile roll; *5* rolled ribbon of glass, with impressed blobs; *6* conveyor belt made of perforated metal plates; *7* blowing heads; *8* carrier belt for 7; *9* glass bulbs blown through the holes in the conveyor belt; *10* split molds carried on conveyor below 6 and surrounding bulbs 9; *11* finished glass bulbs; *12* separator; *13* take-off device; *14* conveyor for bulbs to annealing oven

THE BULB

The pressing of glass for PAR lamps is a completely different operation. Heat-softened glass is cut into chunks, which are placed between two halves of a metal die, one side of which is a plunger. When the plunger is forced into the other half-die, the glass is pressed into the shape of the die cavity. This procces forms reflectors and lenses very accurately, and makes it possible to manufacture PAR type lamps with precise beam control. The reflector and lens of each lamp are fused together in a later step of the manufacturing process, after the filament structure has been mounted in the reflector portion of the lamp.



4.4 Bulb Finishes

In many applications, the high brightness of a tungsten filament is a disadvantage rather than an advantage. In fact, compact high-brightness filaments are advantageous only where accurate light control is desired. Through the years, attempts have been made to reduce the apparent brightness of the filament lamp without impairing its light output. This is accomplished by coating the bulb with diffusing material. The entire bulb then appears to be the light source, rather than just the filament.

4.4.1 Inside Frost

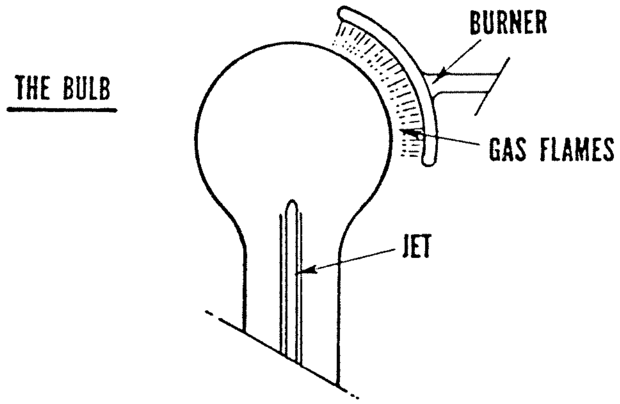
Inside frost is the most popular method of diffusing the light from the filament. In this process, the inside of the bulb is chemically etched. A typical solution for the internal frosting of lamp bulbs has the following composition:

NH_4HF_2	-	42 %
Dextrine (Amylin)		7 %
$Ba\ SO_4$	-	20 %
$Na\ HSO_4$	-	3.5 %
HF		27.5 %

Water should be added until the HF acid content is 18 - 25%. Bulb parts not to be frosted can be protected by a thin coating of wax or paraffin which can later be dissolved in turpentine.

4.4.2 ELECTROSTATIC COATING (Smoke Coating)

Electrostatic coating is being used as a replacement for frosting. The coating is produced by applying an electric field between the burner and the jet. The burner is charged positive. The jet is negative or ground. The bulb is heated by the burner to increase the conductivity of the glass. The gas flame is also used as an electrode. The powder (smoke) supplied is charged negatively when passed through the rubber supply hose, and is attracted by the wall of the bulb and deposited as an internal bulb coating.



Several different materials and mixtures of powders are used to produce different colors:

White	- (Softwhite)
Yellow	- (Bug Light)
Pink	- (Soft Lite)
Jade	- (Jadelite)
Aqua	- (Coolite)

Materials

Wallastonite
Bentonite
Titanium Dioxide
Silica
Nickel Titanate

4.4.3. WHITELIGHT COATING

The inside of the bulbs are coated with Silica Oxide. TETRA-ETHYL-ORTHOSILICATE (T.E.O.S.) is burned with OXYGEN, generating a white smoke which condenses in the form of Silica-oxide particles on the inside of the bulbs, which must be revolving during the process (about 70 R.P.M.)

The Silica-oxide thickness is dependent on --

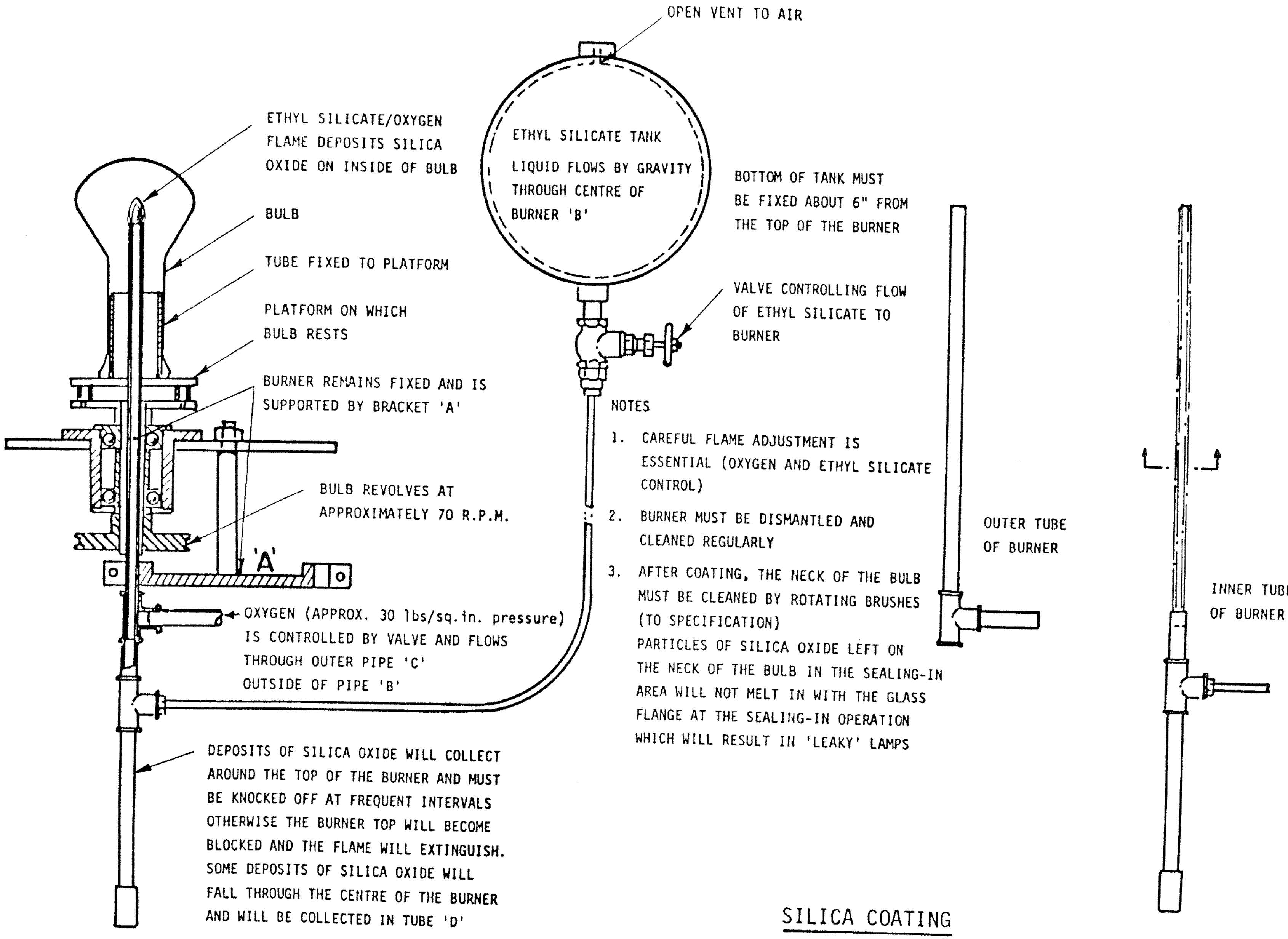
(a) the size of the flame, and

(b) the length of time of the process.

The adjustment of the flame is of great importance and varies according to the diameter of the bulbs being processed. Too large a flame can cause the glass to soften and distort. The flame adjustment can be made by regulating the flow of oxygen and T.E.O.S.

On an apparatus consisting of 8 burners it is possible for one operator to produce about 1000 bulbs per hour. The washed and dried bulbs are usually delivered to the operator on an indexing chain, conveniently positioned for ease of pick up. Adjacent to this chain is a moving asbestos belt on which the bulbs are placed after processing. The bulbs are handled with specially designed tongs which MUST BE WRAPPED WITH ASBESTOS STRING. At the end of the tongs is a probe used for removing deposits of silica-oxide from the top of the burner.

After processing the bulbs are very hot and if they are handled with unwrapped tongs (bare metal) glass cracks will result.



SILICA COATING

(WHITE LIGHTING) OF BULBS

Figure 4.4.3.1

4.4.3 WHITELIGHT COATING-(CONTD.)

The process simply consists of feeding a bulb over the burner, removing it after processing and removing deposits of Silica-oxide from the top of the burner before a new bulb is placed in the head. An experienced operator can process 8 heads in sequence. The flame adjustments must be made to match the speed of operation.

The flames are adjusted with just sufficient oxygen to form whitish-blue flames with only the slightest trace of yellow.

When the flames are burning in air (no bulbs over the burners) they are depositing silica-oxide in the atmosphere, consequently, adequate extraction must be installed. For illustration and description of a typical burner see Figure **4.4.3.1.**

BURNER MAINTENANCE is very important. It is advisable to have two sets of burners and to change them very frequently. Maintenance consists of dismantling the burners completely (unscrew the outer sleeve from the burner). The inner tube must be cleaned on the outside with a stiff brush, leaving the flats well defined and on the inside with a ¼" diameter drill. Remove the trap from the bottom of the burner and empty deposits of Silica-oxide.

When reassembled, the inner tube of the burner must be about 1/16" projecting above the outer tube.

LIGHTING AND EXTINGUISHING THE BURNERS.

The oxygen must be turned on before the T.E.O.S. and turned off after T.E.O.S. This is to prevent the T.E.O.S. firing in the lines.

4.4.3 STORAGE AND HANDLING THE T.E.O.S.

T.E.O.S. must be stored in air-tight containers away from naked flames. Prolonged contact with air (moisture in the air) will cause precipitation of silica gel and will render the liquid useless.

NECK WIPING.

The necks of the bulbs must be wiped clean by means of fast rotating brushes. The loosened silica oxide is kept out of the bulbs by extraction (slots in the brushes) and by a clean dry stream of air blown into the centre of the bulbs.

IT IS VERY IMPORTANT TO SEE THAT THE NECKS OF THE BULBS ARE FREE FROM SILICA OXIDE, ESPECIALLY IN THE SEALING-IN AREA, otherwise particles of Silica-oxide in the seal will cause small pin-hole leaks.

STORAGE OF COATED BULBS

As the Silica-oxide coating absorbs moisture very readily (from the atmosphere), the coated bulbs must be sealed into lamps and pumped the same day as they are processed. Any processed bulbs left unsealed must be stored in a cupboard or room where the temperature is maintained at 70^{o}F. Trays of Calcium Chloride (a drying agent) must be placed in the room to absorb moisture from the atmosphere. The quality of bulbs must be kept to a minimum (say 600 bulbs) and the storage time must not exceed 2 days.

4.4.4. Ceramic Coatings

Red, green and blue colors are not available in smoke coatings. For these colors, the bulbs are coated on the outside by ceramic enamel. Outside ceramic enamels, sprayed finishes, and dip coatings can be used on bulbs to color light. Ceramic enamels are fused to the bulb by heat to form a hard vitreous surface. These are esentially glass-on-glass coatings, and are resistant to scuffing and chipping. Enamels are applied to the glass bulbs before the bulbs are made into lamps.

4.4.5. Metallization (Reflector Coatings)

One of the most important bulb finishes is the application of silver or aluminum to some portion of the glass bulb to control the light distribution from the filament by reflection.

A. Platinum Bright

This process is specially suited to firing-on layers of Pt, for glass, quartz, and glazed or unglazed ceramic substrates. The carefully cleaned, and, in particular, degreased surface is thinly brushed, sprayed or stamped with a solution of chloroplatinicacid (H_2PtCl_6) in alcohol, and containing oil. This is sold under the name "platinum bright"; it is made by such firms as Heraeus-Platinschemelze, Hanau; Johnson and Matthey, England; and Deutsche Gold-Und Silberscheideanstalt (Degussa), Frankfurt am Main.

A. PLATINUM BRIGHT - (CONTD.)

In a similar way, Au, Ag, Ir, and Pd layers can be made with corresponding solutions as carriers, and are marketed under the names "gold-bright"; "silver-bright", etc.

B. Chemical Silvering

All methods of this type consisting of precipitating Ag from ammoniacal silver-nitrate solutions by means of a reducing solution. Among the best known are three methods: the formaldehyde, the Seignette salt or Rochelle salt, and the sugar method. Many variants of each are used in practice.

C. Evaporated Metals

In this process, a heating coil with the metal to be evaporated is inserted into a bulb. The assembly is evacuated to about 10^{-5} Torr and the current is supplied to the heating coil, first to degas and then raised to evaporate the metal which will then condense on the inside glass surface. A tungsten filament is used to evaporate a piece of aluminum ribbon for aluminum coating. A tantalum filament is loaded with a silver ribbon for silver coating. The face of the bulb can be masked by loading glass beads into the bulb to a level desired before coating. Aluminum is less expensive and easier to use but silver has 5% greater reflectivity.

C. EVAPORATED METALS - (CONTD.)

The process must be well maintained at all times and the bulbs and materials must be clean and dry. A small amount of oil or moisture will result in brown or blue coating. A poor vacuum will result in light coatings in some areas.

4.4.6 Staining

Staining is a very special effect caused by applying certain metal salts to a bulb's outer surface, usually the lens area only. This is done either by spraying or dipping. Upon being strongly heated, the surface of the glass is penetrated by the metallic ions present. The color red is used for infrared lamp lenses.

4.4.7 Outside Protective Coatings (Transparent Coatings)

Colored lacquers and silicone coatings are used on the lens area of PAR 38 and other reflector types. The silicone coating is considered weatherproof. These coating materials are available in red, pink, yellow, blue, amber, green and blue white.

The colored lacquers are an alkyd paint which is sprayed on the outside of the finished lamps. It is most important that the lamps be clean and dry. The lamps should be free of soldering flux.

Some protective coatings provide a protection for soft glass types against failure due to weather conditions.

4.4.7 OUTSIDE PROTECTIVE COATINGS (TRANSPARENT COATINGS)-CONTD.

This merely is a means for making an inside type lamp perform reasonably well in foul weather. The second type of protective coating is silicone rubber coating of low light absorption. This provides the lamp user with protection against flying glass when a bulb is broken and further performs a weather-proofing function. Lamps so coated are used in shipyards, garages, freight terminals, outdoor displays, and many other instances where more than normal abuse is likely.

4.4.8 Dichroic Coatings

Dichroic coatings are made up of multiple layers of two materials which have been vaporized under proper vacuum conditions. Each layer is made to a definite thickness, usually a fraction of the wave length of visible light. A complete coating may include from about eleven to thirty-one layers. The number of layers, their composition, arrangement and thickness, determine the band of the visible spectrum transmitted through the glass. Any band from red to blue can be produced. PAR-38 lenses can be coated easily. The dichroic coating can be designed and manufactured with little or no energy absorption. Lamp wattages can be reduced by 35% with dichroic lamps to give comparable light output to those using other coatings available.

4.4.8 Dichroic Coatings (Contd.)

A very special reflector is called a dichroic reflector. Again this reflector is made in a manner not unlike the process for making dichroic colored lenses. In this situation, the composition of the thin layers is so designed that only visible light is reflected from the surface. The infrared energy is largely transmitted and does not heat the subject matter being illuminated as happens with other reflector types. For these reasons, this type of reflector has become widely used in photography, picture projection, and wherever the excess heat from projection, spot and flood lamps is objectionable. Light from a dichroic reflector is called a "cool" light.

The dichroic coatings of whatever design, for either color or heat control, are often made with combination layers of zinc sulfide and magnesium fluoride. In certain cases when the operating temperature is high, combination layers of titanium dioxide and silicon dioxide are used.

4.5 REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

1. Materials Of High Vacuum Technology by W. Espe; Pergamon Press Inc., 44-01 21st St., Long Island City, New York 11101

2. Glass Coatings by Stanley M. Dunn, GTE Sylvania, Inc., 71 Loring Avenue, Salem, Massachusetts 01970

3. Incandescent Lamps by Wilfred G. Matheson, GTE Sylvania Inc., Danvers, Massachusetts 01923

4. Apparatus For Electrostatically Coating Bulb Interiors U. S. Patent #3,999,508

5. Electrostatic Coating Of Silica Powders On Incandescent Lamps U. S. Patent #4,081,709

6. Incandescent Lamp With Improved Coating and Method U. S. Patent #4,099,080

7. Corning Glass Company Bulletins

8. Illuminating Electrical Society Handbook from I.E.S. Society

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FILL GAS

5.0 The purpose of the fill gas is to protect the filament from oxidixation or any other chemical attack and at the same time retard tungsten evaporation from the filament. The use of fill gas allows much higher filament temperatures, higher luminous efficacy and longer life for lamps above approximately 0.2 amps. Lamps below 0.2 amps are usually vacuum lamps.

The laws governing evaporation rates are modified by the presence of the fill gas. The activity of the gas, its molecular structure, molecular weight, pressure, impurity content, as well as the filament geometry, filament position and thermal currents are among the most important parameters to be considered.

The gases commonly used for lamp filling and typical application include:

N_2	Nitrogen	100% - Projection Lamps
Ar	Argon	100% - Low Volt Automotive Lamps
Kr	Krypton	100% - Low Volt Automotive Headlight Lamps
Xe	Xenon	100% - Miners' Lamps
H_2	Hydrogen	100% - Flashing Lamps

With the exception of N_2 and H_2, the filling gas is usually a mixture of N_2 and either Ar, Kr, or Xe. The mixture is necessary to prevent arcing or instant failure at voltages above approximately six volts.

5.1 SELECTING A FILL GAS

The filling gas is chosen to provide a balance between suppression of evaporation of the filament and arcing (flash-over between leads). The ability to suppress filament evaporation increases with molecular weight.

Table 5.1.1 shows important properties of fill gases.

TABLE 5.1.1

Name of Gas		Nitrogen	Argon	Hydrogen	Krypton	Xenon
Chemical Symbol		N_2	Ar	H_2	Kr	Xe
Molecular Weight		28.016	39.944	2.016	83.70	131.3
Specific Gravity Air = 1 (70°F.1 Atm)		0.9670	1.380	0.06950	2.894	4.560
Density 70°F. 1 Atm.		.07247	.1034	.005209	.2169	.3417
NORMAL BOILING POINT	°F	-320.45	-302.55	-423.0	-243.81	-162.51
	°C	-195.8	-185.7	-252.7	-151.8	-109.1
	°K	77.3	87.4	20.4	121.3	164.0
Breakdown Voltage		Approx. 2500	250		420	500

Pure N_2 has a flashover potential ten times higher than pure Argon but heat losses by conduction through Nitrogen would be high and the reduction of **W** evaporation would be less in N_2. A mixture of N_2 + Ar, K, or Xe is necessary. The N_2 should be kept to a minimum. It is not possible to calculate the flashover voltage of a mixture from the physical characteristic of its components. Flashover is also suppressed by additions of H_2, H_2O vapor and inside bulb coatings of silica powder.

5.1 SELECTING A FILL GAS - (CONTD.)

The following table shows some common gas mixtures and applications:

TABLE 5.0.2

Mixture	Filling Pressure	Application
92 Ar:8 N_2	650 Torr.	40 - 100 Watt G.L.S.
88 Ar:12 N_2	600 Torr	100 Watts & Over G.L.S.
72 Kr + 8 Xe + 20 N_2	600 Torr.	Krypton G.L.S. Lamps

5.2 Evaporation Rate and Life as a Function of Fill Gas

The evaporation rate of incandescent **W** filaments with pure Kr is only 60% of that with pure Ar and is even lower with Xe. Kr and Xe are much more expensive than Ar and are only used for special lamps. The mixing of the pure gas with various amounts of N_2 increases the evaporation rate of **W**.

5.3 Effect of Fill Gas Pressure

Both arc suppression and evaporation rate are improved by increased pressure. The evaporation rate at a given filament temperature varies inversely with the pressure. Double the pressure reduces evaporation rate by a factor of two and thus doubles the life of the lamp. Pressure is limited by bulb geometry, bulb size, and application. G.L.S. lamps are filled to a little less than atmospheric and in operation the internal pressure is atmospheric or a little above. Some small quartz lamps run at ten atmospheres or more.

5.4 THERMAL CONDUCTIVITY OF FILL GASES

The thermal conductivity of the filling gas varies with its molecular weight. The thermal conductivity also varies with the fill gas pressure. Table 5.4.1 shows the thermal conduction of fill gases as a function of the temperature.

TABLE 5.4.1

Thermal Conduction, φ, Expressed in Watts Per Cm for Various Gases

T, °K	N_2	A	Kr	Xe
0	0	0	0	0
200	0.017	0.013	0.007	0.004
400	0.064	0.048	0.025	0.015
600	0.133	0.100	0.053	0.031
800	0.228	0.166	0.089	0.052
1000	0.345	0.245	0.132	0.077
1200	0.485	0.336	0.184	0.108
1400	0.650	0.437	0.243	0.143
1600	0.839	0.551	0.309	0.182
1800	1.055	0.674	0.380	0.225
2000	1.291	0.811	0.459	0.271
2200	1.548	0.960	0.544	0.322
2400	1.825	1.119	0.634	0.375
2600	2.126	1.288	0.728	0.431
2800	2.447	1.469	0.828	0.491
3000	2.787	1.660	0.932	0.553
3200	3.154	1.856	1.039	0.617
3400	3.539	2.068	1.153	0.685

5.5 MIXING FILL GASES

The mixing of gases also affects the thermal conductivity of the fill gas.

Fill Gas	Relative Thermal Loss
N_2 100% (570 Torr)	498
87 Ar + 13% N_2 (570 Torr)	392
87 Kr + 13% N_2 (570 Torr)	301
Ar 100% (570 Torr)	299
Kr 100% (570 Torr)	169
Xe 100% (570 Torr)	100

In all cases the thermal loss varies with lamp wattages and filament wire size. The higher the wattage, the lower the thermal losses due to the fill gases.

5.6 Light Fill Gases Vs. Heavy Fill Gases

The net result of gas filling with heavier gases is as follows:

	Light Gas	Heavy Gas
Gas Cost	Low	High
Bulb Size	Big	Small
Lamp Efficiency (Lpw)	Low	High
Lamp Life	Low	High
Bulb Temperature	High	Low
Flashover Voltage	High	Low

In commercial G.L.S. coiled coil lamps with Kr/N_2 (600 Torr) fillings, the light yield is 4-11% higher than Ar/N_2 (90/10) filled lamps of equal rating. Xenon fillings gives three times the life of Kr filled lamps of same Lpw or 17% more light at the same life.

5.7 EFFECT OF CONTAMINANTS IN FILL GAS ON LAMP PERFORMANCE

The purity of the fill gas is a major factor in lamp life. The impurities usually react chemically with the filament.

Gas	Relative Evaporation	Relative Lamp Life
Vacuum	100%	1.0 Hour
N_2 100% (600 Torr)	4%	25 Hour
86 Ar + 14 N_2 (600 Torr)	2.5%	40 Hour
Ar 100% (600 Torr)	2%	50 Hour
Kr 100% (600 Torr)	1.2%	83 Hour
Xe 100% (600 Torr)	1.0%	100 Hour

Argon gas can be obtained as pure argon (99.99%) or as a mixture with pure nitrogen used as a diluent to obtain any desired degree of argon purity. The most common mixtures used for lamp filling gases are 99.9%, 98%, 95, and 88% argon, with 50% argon being used in a few special cases.

The evaporation rate varies in Ar/N_2 mixtures as a function of the N_2 content. Lamp life varies with the evaporation rate.

Mixture Ar	Mixture N_2	Relative Evaporation	Relative Lamp Life
100	0	100	100 Hours
98	2	100.85	98.15
96	4	103.79	96.21
92	8	107.76	92.24
90	10	109.77	90.23
88	12	111.80	88.20
86	14	113.83	86.17

5.7.1 OXYGEN

Oxygen is probably the most common impurity left in lamps after exhaust and, because its action is more moderate than that of some of the other impurities, slight traces may show no apparent damage. Oxygen combines readily with tungsten at red heat, and more rapidly as temperature increases. The oxides formed at the hot filament volatilize and are carried by the gas stream to the bulb walls and other cooler parts of the lamp, where they condense to produce their characteristic deposits.

The composition of the oxides formed, and the appearance of the deposit produced will vary with the amount of oxygen present and the temperature at which they are formed. A 0.2% mixture of oxygen in the lamp atmosphere will produce a thick yellowish-white deposit of tungsten oxide (WO_3) which covers the interior of the lamp. With lower percentages of oxygen, the color of the oxide being produced will vary from white to light blue and finally dark blue. With these smaller amounts of oxygen, the deposit on the bulb wall or lead tips may appear as a brown or black color which can be confused with the discoloration caused by other impurities.

The action between the tungsten filament and oxygen (by itself) will occur at initial light-up and this action becomes complete as soon as the oxygen is used up. No further discoloration, other than the normal darkening due to the deposition

5.7.1 OXYGEN - (CONTD.)

of evaporated tungsten, should therefore occur throughout the life of the lamp, unless the lamp is a leaker and additional oxygen is introduced through breathing-in of atmospheric air. The oxide deposit produced by slight traces of oxygen in the atmosphere of lamps having a large bulb surface area may therefore not be readily apparent and cause no appreciable loss in light output. However, the attack of the oxygen on the tungsten may be localized at certain critical temperature points along the filament to produce hot spots which can cause shortening of lamp life. Moreover, if hydrogen is also present by degassing from metal parts, it can react with the tungsten oxide deposits producing water and the destructive water cycle.(5.7.2)

Traces of oxygen in a lamp can usually be detected by burning the lamp at low voltage for a few minutes. The voltage to be used should be just enough to produce a red color to a few of the center turns of the filament. If any appreciable amount of oxygen is present, it should cause oxidation of the tungsten. However, at this low temperature there should be little or no vaporization of the oxide so it should remain on the coil as a dark discoloration after the lamp is turned off. This can be followed by a light-up at full voltage which should produce a slight puff of smoke as the oxide volatilizes off the filament. Larger quantities of oxygen will usually produce some discoloration on the bulb wall as the oxide flashes off.

5.7.2 WATER VAPOR

Water vapor is one of the more stubborn impurities to remove from the lamp during the exhaust process. If present in the finished lamp atmosphere, its effect on lamp performance is similar to that of oxygen but considerably more vicious in that it has a recurring action commonly known as the water cycle.

Water vapor in the region of the hot filament, becomes dissociated into its elements - hydrogen and oxygen. The free oxygen readily combines with the hot tungsten, to form tungsten oxide, which volatilizes and is carried away by the gas stream to be deposited in the cooler areas of the lamp interior. The intense heat of the filament also causes the molecular hydrogen to dissociate into hydrogen atoms. The hydrogen, in this very active state, is able to reduce the tungsten oxide to leave metallic tungsten which may appear as a grey or black deposit on the bulb wall, or produce a sooty appearance on the lead tips and support loops. This reduction process may proceed through several intermediate stages as the tungsten oxide is transformed through the various lower oxide forms. The color of the deposit may therefore be tinted with any one, or a combination, of the characteristic colors of these lower oxides which include green, blue, violet and brown. However, the temperature within a normally burning lamp is, for the most part, high enough to cause complete reduction and the deposit will usually be predominately grey or black.

5.7.2 WATER VAPOR - (CONTD.)

The reaction, in which the tungsten oxide is reduced, simultaneously recreates water vapor which will again attack the hot filament and this repeating cycle will go on unhampered throughout the life of the lamp. Lamps containing only a trace of water vapor will show abnormal blackening early in lamp life but the blackening will also continue to progress at a more rapid rate than that due to the normal evaporation of tungsten from the incandescent filament.

In addition, the attack on the tungsten usually occurs at certain critical temperature points along the filament.

This results in necking down of the wire to form hot spots and cause early burnout. The thinner spots of the filament will also have much reduced shock resistance.

5.7.3 Carbon and Carbon Compounds

Carbon as a single impurity in a lamp does not cause blackening but can produce brittleness and distortion of the tungsten filament. On the other hand, if carbon is present along with oxygen, in either a combined or free state, blackening together with the characteristic filament embrittlement and filament distortion or squirm will be produced.

Hydrocarbons, in the form of oil vapors, can be carried into the lamps during the exhaust process, if the machine lines are not kept clean. Such hydrocarbons will dissociate, at filament operating temperatures, and react with the hot tungsten to form carbides and produce the brittleness and squirm.

5.7.3 CARBON AND CARBON COMPOUNDS - (CONTD.)

In addition, the freed hydrogen, in the presence of oxygen, sets the stage for the water cycle which will continue to cause abnormal blackening throughout the life of the lamp. The oxides of carbon (CO and CO_2) also can produce a blackening. Carbon dioxide can dissociate in the higher temperature regions of the lamp, to form carbon monoxide and oxygen. There are also several reactions which can occur between carbon monoxide and the tungsten, depending upon the temperature conditions. In addition, because of the temperature gradients in the lamps, these reactions become reversible to produce a cycling condition in which the tungsten is gradually removed from portions of the filament and deposited on the bulb wall or other parts of the lamp which may be at the appropriate temperature.

5.8 Methods of Purifying Lamp Fill Gases

In most new lamp plants, N_2 and Ar are purchased as liquids and then evaporated and mixed to make lamp gases. Gases from liquids are quite clean. However, when the gas is passed through pipes, etc., the gas can become contaminated.

5.8 METHODS OF PURIFYING LAMP FILL GASES - (CONTD.)

The following Table 5.8.1 shows the levels of contamination that should not be exceeded.

TABLE 5.8.1

GAS PURITIES -- FILLING OR FLUSHING

Oxygen	$<$ 5.0 PPM
Hydrogen	nil
Carbon Dioxide	$<$ 0.5 PPM
Hydrocarbons	$<$ 2.0 PPM
Water	$<$ - 76°F dewpoint

NOTE: These values are readily attainable from liquid sources. System operation and maintenance must be rigidly controlled. Many installations need in-house purification especially for gases purchased in cylinders. Analysis equipment is recommended.

Purification of the gases can be at the source or at the exhaust machine. The best place is at the exhaust machine even though a purifier is needed at each machine instead of one purifier at the source.

5.8 METHODS OF PURIFYING LAMP FILL GASES - (CONTD.)

Table 5.8.2 shows several absorber materials (getters) and the contaminants they will remove.

TABLE 5.8.2

Getter Capacities for Gases and Metals

Getter Material	Gas					
	CH_4	CO	CO_2	H_2	N_2	O_2
Ba	0	0.2	0.2	0	0	1
Sr	...	0.1	...	...	...	...
Mg	...	0	...	...	...	...
Mo	0	0.15	...	0.05	0.05	0.5
Ta	0	0.08	...	0.5	0.1	1
Ti	0	0.15	0.13	2	0.05	1

Centorr Co. of Suncook, N. H. is a source of getter furnaces for fill gas purification. The absorber material is Ti. The furnace temperature is set at 650°C max. At this temperature, H_2, O_2 and H_2O vapor will be gettered. At higher temperatures, the getter material would getter N_2 and become saturated.

The removal of water vapor from the fill gas is the most important gettering operation.

Table 5.8.3 shows the effectiveness of various drying (water vapor gettering) materials.

TABLE 5.8.3

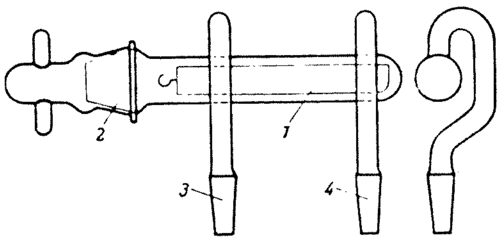
Efficiency of Drying Agents, Measured by Residual Water in mg/liter Gas After Drying at 25°C

Cold filter at - 180°C	10^{-16}
P_2O_5	$< 2 \times 10^{-5}$
$Mg(ClO_4)_2$	$< 5 \times 10^{-4}$
$Mg(ClO_4)_2 \times 3\ H_2O$	$< 2 \times 10^{-3}$
BaO	—
KOH (fused)	2×10^{-3}
Al_2O_3	3×10^{-3}
H_2SO_4	3×10^{-3}
MgO	8×10^{-3}
Silica gel	—
NaOH (fused)	1.6×10^{-1}
$CaBr_2$	2×10^{-1}
CaO	2×10^{-1}
$CaCl_2$(granular)	1.4 to 2.5×10^{-1}
$CaCl_2$(technical grade unhydrous)	—
$CaCl_2$(dehydrated at 250°C)	—
H_2SO_4(95.1%)	3×10^{-1}
$ZnCl_2$	3×10^{-1}
$ZnBr_2$	1.1
$CuSO_4$	1.4

Flow rate about 100 cm^3 air per hr per cm^3 drier.

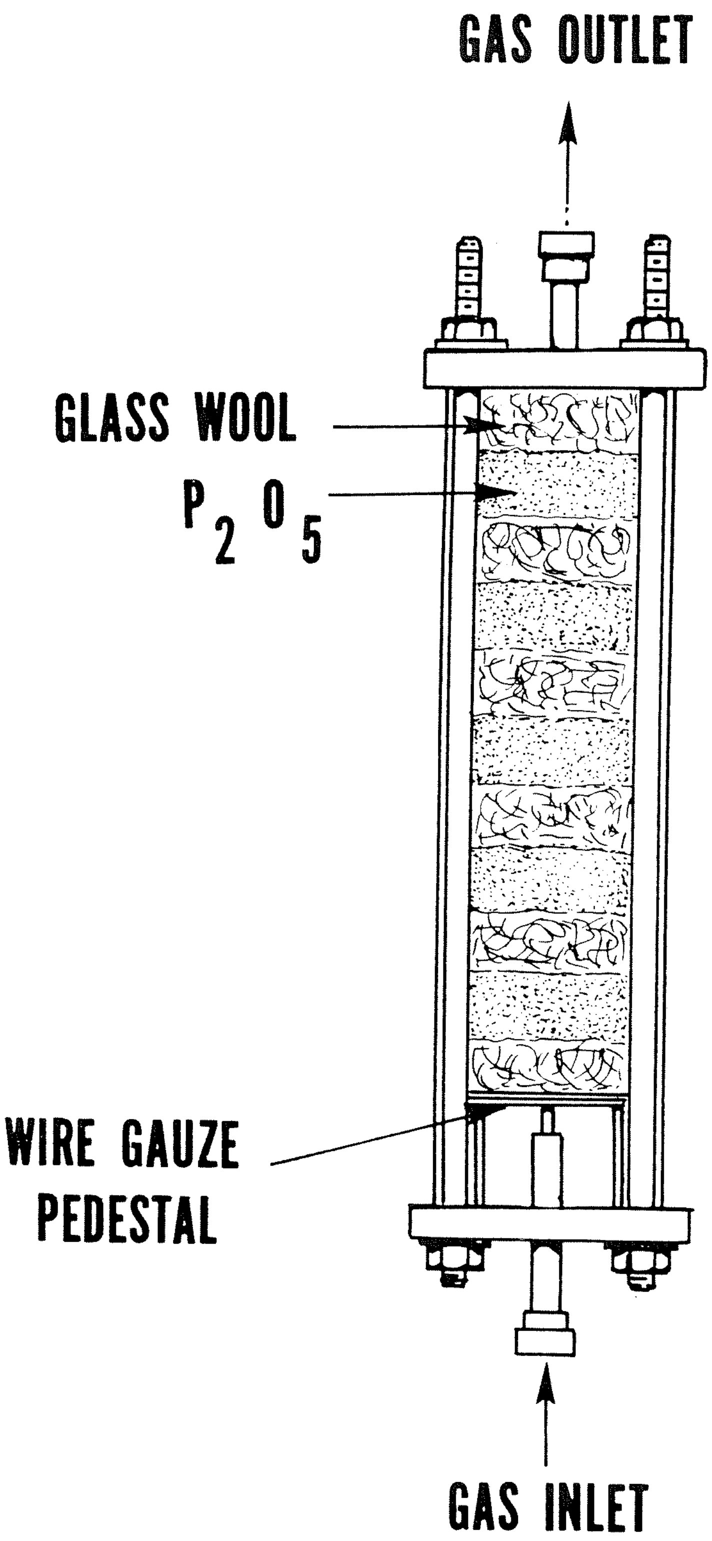
The most effective dryer is phosphorus pentoxide (P_2O_5). When a gas has been sufficiently dried over P_2O_5 the vapor pressure of residual water is only about 3×10^{-7} Torr.

The apparatus to use P_2O_5 can take many forms.



Gas-drier made of glass, with P_2O_5

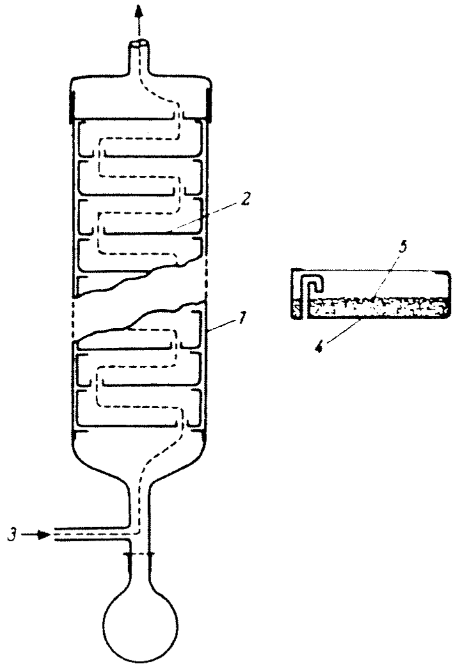
1 porcelain boat with P_2O_5; *2* filling port with ground-glass closure; *3* inlet, and *4* outlet for gas to be dried; *3* and *4* have standard cones for joining to gas lines. The right-hand illustration is an end-on view



IMMEDIATELY AFTER FILLING THE DRIER MUST BE PUMPED AND FILLED WITH ARGON AND THE ENDS PLUGGED-UP.

PHOSPHORUS PENTOXIDE (P_2O_5) DRIER USED IN GAS LINES ON PUMPING SYSTEMS

FILL GAS



Gas-drier with P_2O_5

1 stainless steel outer tube; 2 insert plate provided with layer of P_2O_5 and gas-entry ports in the sides; 3 path of gas when being dried; 4 another form of insert plate; 5 P_2O_5 layer

P_2O_5 used for drying must be free of As and lower oxides of P which would otherwise form volatile compounds with various gases and vapors; for example, water vapor reacts to form highly toxic phosphine (PH_3). They are removed by putting technical-grade material into a red-hot porcelain dish and agitating in a stream of O_2. (Merck produces a phosphorus pentoxide grade properly purified for vacuum work, called Acid, phosphoric. anhydr. albiss. pro anal.) The drying agent is generally inserted in the gas line in a special container (porcelain or glass boat) through a glass port. It is also possible to fill large drying towers with about 500 g P_2O_5 and a number of glass tubes about 20-25 mm long, 15-20 mm dia.; the whole unit is then shaken up thoroughly to distribute the drying agent throughout the tower. After about 100 hr operation, the tower is removed from the gas line and shaken again.

If the pentoxide has become sticky and of honey-like to gelatinous consistency, it should be removed by washing out in hot water and replaced by fresh. In large-scale driers, the drying agent can be placed on metal plates provided with side-holes and the plates stacked vertically in an Fe tube.

P_2O_5 drying bottles for lamp equipment are usually about 15 inches high and about 3 inches in diameter. The inlet is on one side near the bottom and the outlet on the opposite side near the top. The bottle is filled with glass stem flares, glass wool and P_2O_5 granuals such that the input gases must flow in a long path before reaching the outlet. These assemblies are made up in the chemical lab, at the lamp plant.

5.9 Testing Gas Purity

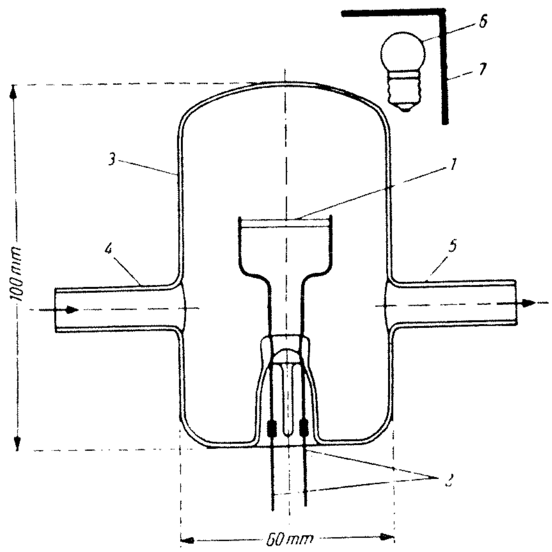
There are commercial devices for continuous recording of water vapor in protective gases, in particular water in H_2 for degassing furnaces; one example is the "Moisture Monitor Type 26-301" of the Consolidated Electrodynamics Corp., Pasadena, Calif., USA. These can determine moisture concentrations over the range 1 to 1000 x 10^{-4}% of the test-gas volume, with reasonable response-times; this amounts to dew-points of -76° to $-20^{\circ}C$ (see Table T20-21). They operate on the principle of simultaneous absorption and electrolysis of water vapor with the aid of an electrolytic cell. The cell consists of two mutually-insulated, closely-spaced Pt wires coated with a film of P_2O_5, and across which a voltage is applied so that measurement can be made of the electrolyte current produced by water absorption.

5.9 TESTING GAS PURITY - (CONTD.)

There are also commercial devices for continuous recording of O_2 in gases, for instance the "Super-sensitive Oxygen Indicator" Model SS-4S made by Baker & Co., Newark, N. J., USA. The principle is determination of the heat developed in a H_2--O_2 reaction on a noble-metal catalyst, and the concentration ranges are 2 to 200 x 10^{-4}% and 200 to 2000 x 10^{-4}% of the test-gas volume. The gas flow rate required is 114 liters/hr at 1 atm pressure.

A common lamp plant test is the "puff test". In this test, the gas is passed over a heated tungsten filament. The filament temperature is high enough to oxidize but not high enough to vaporize tungsten oxide (approx. 1300°C). Oxygen causes the normally bright tungsten to darken. The surface can be renewed by raising the filament temperature and evaporating the WO to condense on the bulb wall. The evaporation is seen as a "puff" of smoke.

Figure 5.9.1 shows a typical lamp plant device.



Indicator tube for traces of O_2 in H_2, N_2 or inert gases

5.10 THE EXHAUST-FLUSH-FILL PROCESS

The term "exhaust", as used in lamp making, refers to the process of obtaining a favorable atmosphere in a lamp enclosure, which will permit the filament to be heated to incandescence to produce an efficient light source for a reasonably long time.

Basically, the primary function of lamp exhaust is the removal of atmospheric air and adsorbed gases from the bulb interior, including the bulb walls and mount parts. Heat is a necessary part of the exhaust process. It is responsible for freeing the adsorbed gases from the surface of the glass and metal parts. The heat may come from the sealing cycle or from an oven in the early part of the exhaust process.

Dry flushing gas, usually N_2, is used to dilute the residual air in the lamp so that any molecules left in the vacuum lamp or mixed with the fill gas will be inert to the filament. There are two types of exhaust cycles - Vacuum (called type B) and gas filled cycle (called type C).

5.10.1 Type B (Vacuum)

The objective of the type B exhaust process is to obtain as good a vacuum as possible in the lamp. This is accomplished by continuous evacuation, and the application of heat to remove as much of the original atmospheric air and moisture as possible in the time available. When a lamp, filled with air at atmospheric pressure, is first connected to a vacuum source, the

5.10.1 TYPE B (VACUUM) - (CONTD.)

initial flow of gas from the lamp into the vacuum system will be at a rapid rate because of the great pressure gradient between the lamp and the vacuum source. However, as the pressure in the lamp approaches that of the vacuum source, the diminishing pressure differential causes the gases to move more and more slowly. As a result, the final stage of attaining the degree of vacuum required for the lamp atmosphere, becomes more difficult and requires the use of a high vacuum source as well as closer adherence to high vacuum techniques. A final pressure of about 1 micron of mercury (.15 Pa) is desirable.

Factors affecting the degree of vacuum which can be attained in the lamps include the length, diameter and configuration of the lines connecting the lamp to the pump, the tightness and cleanliness of the connections in the high vacuum portion of the system and, to some extent, the volume of the lamps being evacuated.

Since there is always some residual gas in a vacuum lamp, flushing with dry N_2 early in the cycle will ensure that the residual gas is N_2 not O_2 or H_2O vapor.

5.10.2 Type C (Gas Filled)

The objective of the type C exhaust process, used for gas filled lamps, is to remove the atmospheric air and moisture from the lamp and introduce a dry inert gas which will serve

5.10.2 TYPE C (GAS FILLED) - (CONTD.)

as the final lamp atmosphere. This is accomplished by a repeated dilution, or rinsing process in which the original air is gradually reduced to a negligible amount and simultaneously replaced by the inert gas (usually an argon-nitrogen mixture). This process consists of an initial rough evacuation to remove the bulk of the air, followed by a series of cycles in which the lamp is alternately flushed and evacuated to controlled pressures, and then finally filled with the required filling gas.

This process does not require the use of a high vacuum source because, at no time, is it necessary to pump the lamp to a pressure below approximately 6mm. In addition, the turbulence produced by the flush gas, as it rushes into and out of the lamp, tends to scrub the adsorbed films of moisture and other impurities from the internal glass and metal surfaces, and this dry gas also acts somewhat like a blotter to pick up the water vapor and aids in removing it.

The extent to which the original air can be removed from the lamp by this flush exhaust process is dependent upon several factors, including:

1) The pressure (P_I) to which the lamp is initially pumped,

2) The pressure (P_F) to which the lamp is flushed

5.10.2 TYPE C (GAS FILLED) - (CONTD.)

3) The pressure (P_V) to which the lamp is pumped after each flush, and

4) The number of times (n) the lamp is flushed.

These factors can be arranged into a simple formula which can be used to calculate the partial pressure of air (P_A) due to the original atmospheric air, remaining in the lamp after any number of flushes or with any combination of in-process pressures.

$$P_A = P_I \left[\frac{P_V}{P_F} \right]^n$$

All lamp pressures (P_I, P_V and P_F) are in terms of mm Hg (absolute) and they represent actual pressures attained in the lamps at some common temperature. For convenience, these pressures are usually measured at room temperature and corrected to 25°C (77°F) to provide a common base for all measurements.

The partial pressure (P_A) of the residual air will also be expressed in terms of mm Hg at this same temperature, but it can be converted into the more common form, of parts-per-million (PPM) of the total gas in the finished lamp, by substituting the calculated value for P_A in the following expression.

$$\text{PPM (air)} = \frac{P_A}{P_L} \times 10^6$$

5.10.2 TYPE C (GAS FILLED) - (CONTD.)

where P_L is the final lamp filling pressure (in mm of H_g)

The following table shows the same results can be obtained without pumping to a high vacuum:

Case I A-19 Bulb

1. Pump to 10 Torr — PI = 10
2. Flush to 100 Torr — PF = 100
3. Pump to 10 Torr — PV = 10
4. Repeat 2 & 3 four times — n = 4
5. Fill to 650 Torr — PL = 650

$$PPM\ (air) = \frac{PI \left[\frac{PV}{PF}\right]^n}{PL} \times 10^6$$

$$= \frac{10X \left[\frac{10}{100}\right]^4}{650} \times 10^6$$

PPM (air) = 1.538

Case II A-19 Bulb

1. Pump to 1 Torr — PI = 1
2. Flush to 1000 Torr — PF = 1000
3. Pump to 100 Torr — PV = 100
4. Repeat 2 & 3 three times — n = 3
5. Fill to 650 Torr — PL = 650

$$PPM\ (air) = \frac{PI \left[\frac{PV}{PF}\right]^n X10^6}{PL} = \frac{1 \left[\frac{100}{1000}\right]^3 X\ 10^6}{650}$$

PPM air = 1.538

5.10.2 TYPE C (GAS FILLED) - (CONTD.)

Note that in Case II, the initial pump down was lower but the flush pressure and pumps were higher and that only 3 flush pump cycles were used to equal 4 in Case I.

The use of high pressure flush and pump cycles results in much faster exhaust cycles. The following table shows the time to pump some standard lamps to various pressures. The fill pressure in all bulbs is 800 Torr.

Time	A-19 (132cc)	R-30 (287cc)	R-40 (705cc)
.5 sec.	110	244	491
1.0 sec.	40	135	371
1.5 sec.	15	74	280
2.0 sec.	6	41	212

The table shows that for viscous pumping range (1000 Torr & down to 1 Torr) the pumping speed is much faster at higher pressure differential between lamp and pump manifold.

Speed varies with $\frac{a}{\ell}^4 \propto$ pressure differential, ΔP, where (a) is radius of exhaust tube, ℓ is length of exhaust tube and ΔP is pressure in lamp minus pressure in pump manifold. The data shows that the time to pump from 100 Torr to 10 Torr in Case I is approx. (1.75 -.5 sec.) 1.25 seconds per cycle. With 4 cycles, 4 X 1.25 = 5 seconds. In Case II the time to pump from 1000 Torr to 100 Torr is approx. .5 seconds.

5.10.2 TYPE C (GAS FILLED - (CONTD.)

With 3 cycles, 3 x .5 = 1.5 seconds and even with an extra .5-1 sec. for initial pumping to 1 mm instead of 10, there is considerable pumping time saved. The following rules of thumb hold for processing gas filled lamps.

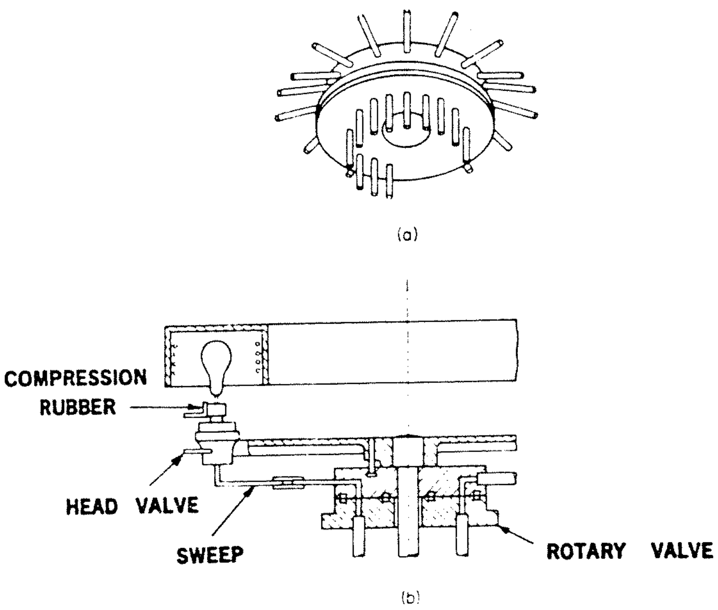
1. Heat bulb as hot as possible before exhaust either by sealing cycle or by oven on exhaust cycle. If oven is used, flush lamp to approx. 800 Torr after leak checking and do not pump until after maximum oven temperature is reached.
2. Pump to less than 5 Torr before first flush.
3. Flush to at least 760 Torr.
4. Pump to less than 100 Torr.
5. Allow at least 3 flush-pump cycles.
6. Pump to at least 1 Torr.
7. Fill to specified pressure.

The residual air should calculate to be less than 5 PPM. Values less than 1 PPM are not realistic because of inherent contaminants in the flush and fill gas.

5.10.3 The Exhaust-Flush-Fill Equipment

The exhaust machine is an indexing turret type machine. The sequence of operations required for applying the flush-exhaust process is controlled by a rotary valve located at the center of the machine. Figure 5.10.3.1 (a) is an external view of a complete valve. Figure 5.10.3.2 is a view of the inner surface of a typical valve.

5.10.3 THE EXHAUST-FLUSH-FILL EQUIPMENT - (CONTD.)



Lapped seal used in slide valve: (a) side view of slide valve; (b) cross section through the slide valve of an exhaust machine

Figure 5.10.3.1

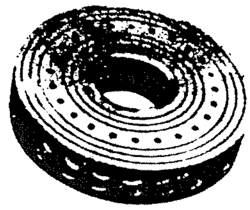


Figure 5.10.3.2

Each head is connected to the valve by an individual pipe (sweep). The heads are equipped with compression rubber fittings which provide an air-tight seal to the exhaust tube. A valve is integral with the exhaust head which either connects or isolates the lamp from the sweep to the center rotary valve.

In traveling around the machine, each lamp is first connected to a preliminary vacuum source (rough pump) which reduces the pressure for a leak check. This is followed by more pumping (fine pump) and then flushing. Figure 5.10.3.3 shows a sequencial operation. Figure 5.10.3.3 is not necessarily typical because different size lamps and production speeds require different cycles.

EXHAUST-FLUSH-FILL EQUIPMENT

Typical Rotary Combination Flush and "Hard Pumping" System

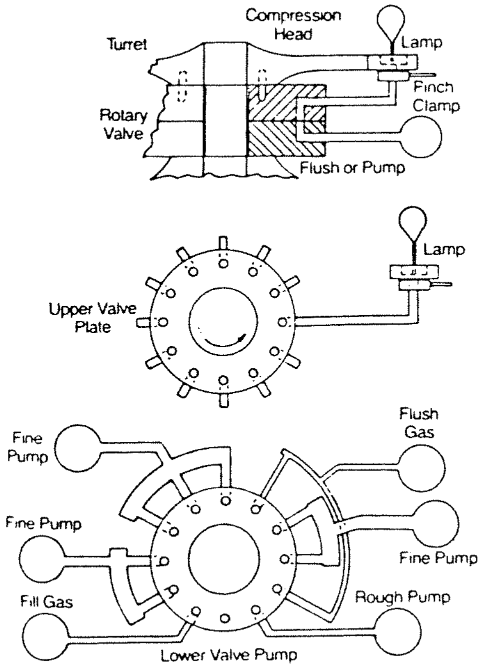


Figure 5.10.3.3

Rotary Fly Flush Pumping System

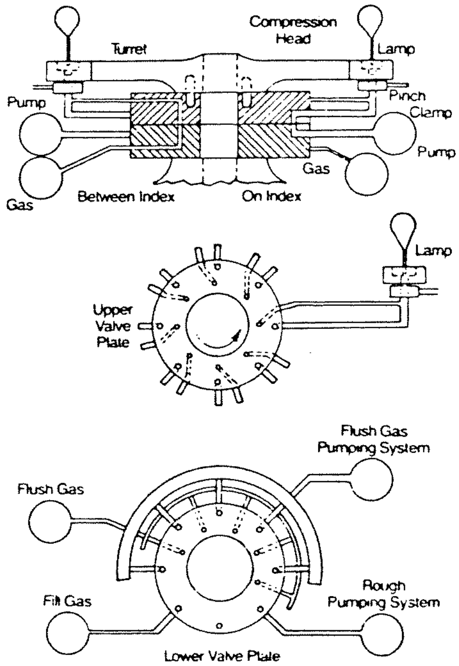


Figure 5.10.3.4

5.10.3 THE EXHAUST-FLUSH-FILL EQUIPMENT - (CONTD.)

Figure 5.10.3.4 shows a system where less pumps and more flushing is utilized. The stationary rotary valve part (Figure 5.10.3.1 (b) is the input for the vacuum pumps, the flush gas and the fill gas.

When the lamp has been pumped and flushed to the desired dilution level, the next step is to pump to as high a vacuum as practical within the time and equipment available. The next step is to fill the lamp to the required pressure. If there is any residual gas in lamp-head-sweep system before fill, the fill gas will push the gas into the lamp and thus change the gas mixture. In most cases this will not be terribly significant if residual gas is pure N_2. After filling, the lamp is removed from the system by tipping-sealing off exhaust tube with a gas-oxygen flame.

There are a lot of variations in exhaust cycles, some machines employ fly flushing. In this operation, the flush gas port in the valve is half way between dwell positions. The gas is supplied to the lamp as the head port passes over the fly flush port during index. The time is so short, that only low gas pressure occurs - usually less than 100 Torr. When fly flush is used, as many as 9 flush-pump cycles are used. As speeds increase, fly flush becomes less attractive.

5.10.3 THE EXHAUST-FLUSH-FILL EQUIPMENT - (CONTD.)

Filling is the opposite of pumping. When the bulb is at vacuum, the fill gas rushes into the lamp. As the pressure in the lamp increases, the pressure differential becomes less and the pressure rise rate decreases. For some lamps, more than one fill position is required. The fill gas pressure has a direct bearing on the performance of the lamp when it is put into service.

The final pressure in the lamp is a function of tipping technique.

5.11 Tipping (Pinch Off)

5.11.1 Vacuum Tip

This method requires that the pressure in the lamp be less than atmospheric. When heated, the exhaust tube collapses from external pressure and seals off the lamp. The tubing is then pulled to a thin thread of glass and severed by the flame. Excess glass is balled up on the tip by tipping fires and surface tension of the glass.

5.11.2 Vent to Atmosphere Tipping

In this system, the lamp is filled to about 200 Torr above atmospheric and then allowed to leak back through the plate while being heated by the tipping fires. With no pressure differential, the exhaust tube neither expands or contracts. Close off is accomplished by pulling exhaust tube to a fine

5.11.2 Vent to Atmosphere Tipping

thread which finally closes by surface tension of glass, the tube is severed by flame and balled back as in vacuum tip. The vent tip is strong and has good geometry. The pressure in a vent tip lamp is about 50 Torr higher than in the best vacuum tip.

5.11.3 Press Tip

The press tip is accomplished by mechanically pressing the exhaust tube, after the tube is softened by heating. The process is critical because the pressure in the lamp is usually above atmospheric and will thus tend to expand and blow out when the glass is softened. Control is obtained by heating the shortest length of the tube necessary and to use a small bore heavy wall exhaust tube. Since a small bore is disadvantageous in pumping the tube is restricted by stretching just before the positive pressure is added. In this manner, a small bore, short section is achieved for pressing. Internal pressures up to 1200 Torr or more are possible with press tipping.

5.11.4 Freeze Out Tipping

In this method, the fill gas in the lamp is frozen by immersion of the lamp in liquid nitrogen. When the fill gas condenses, a vacuum results and the tip is a typical vacuum tip. After tipping, the fill gas vaporizes and final pressure

5.11.4 FREEZE OUT TIPPING - (CONTD.)

is achieved. Fill pressure of 10 atmospheres or more are achievable by this method.

With the exception of the freeze out method, the temperature of the bulb at tipping is a major factor controlling the cold bulb fill.

$$P_1T_2 = P_2T_1$$

P_1 = Fill pressure Torr abs.

P_2 = Unknown Torr abs.

T_1 = Glass temperature at tipping (absolute temperature)

T_2 = Room temperature (absolute temperature)

Example:

P_1 = 650 Torr

T_1 = 375^oK (100^oC)

T_2 = 298^oK (25^oC)

P_2 = X

650 X 298 = 373 P2

P2 = 519 Torr

Since lamp life varies directly with pressure, cold fill pressure should be as high as possible.

5.12 REFERENCES FOR ADDITIONAL IN-DEPTH INFORMATION

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2. Scientific Foundation of Vacuum Technique by S. Dushman, John Wiley & Sons, Inc., New York.

3. Exhaust & Fill Cycles for Incandescent Lamps by D. R. Dayton, GTE Sylvania, Danvers, Mass.

4. Materials of High Vacuum Technology by Espe
Pergamon Press, 44-01 21st Street, Long Island City, N. Y., 11101.

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6. Vacuum Sealing Techniques by A. Roth, Pergamon Press, 44-01 21st Street, Long Island City, N. Y. 11101.

7. Exhaust Systems Training Package
GTE Sylvania Equipment Development Plant, Ipswich, Mass.

8. Theory-Design and Installation of Rotary Exhaust Slide Valves by D. R. Dayton, GTE Sylvania, Estes St., Ipswich, Mass. 01938.

9. The Collected Works of Irving Langmuir; Pergamon Press, 122 East 55th St., New York 22, N. Y. Volume II.

LAMP FAILURE MECHANISMS

6.0 The life of an incandescent lamp is controlled by several factors.

1. The temperature of the filament.
2. AC or DC lamp current.
3. The mass of the filament.
4. Arcing.
5. The environment surrounding the filament.

The temperature of the filament controls the evaporation rate of the tungsten filament and also the luminous efficacy to the lamp. The mass of the filament is a function of current and filament geometry. The environment surrounding the filament can either be a vacuum or an inert gas. The quality of the environment is a function of exhaust and or fill cycle.

A perfect incandescent lamp operated at constant voltage would have an infinite life. The infinite life is a result of a uniform decrease in wire diameter due to evaporation. The decrease in diameter would cause an increase in resistance to result in a decrease in temperature.

However, in the real world there are no perfect incandescent lamps; the filament wire burns through or fractures at a point in a finite time due to a hot spot which forms and fails while the evaporation from the remaining filament is still quite small.

6.1 Failure Due to Wire Temperature

There are many mechanisms which cause high temperatures and thereby cause premature failure.

6.1.1 KEYHOLING

Keyholing results when a filament sags and becomes loose enough to loop around a support. The loop shorts out part of the filament and thereby raises the current and overheats the remainder of the filament.

6.1.2 Loose Clamps.

When the filament tail is loose in the clamp I^2R heating occurs which can destroy the filament. When leg type single coils are clamped, loose clamps can occur due to overclamping. The tungsten wire is necked inside the clamp and then becomes loose. In subminiature lamps, the filament tail must break through the borate layer on the dumet for good contact.

6.1.3 Close Turns.

Even a single pair of close turns will cause a localized hot spot on the filament. With a wide pitch filament, a small change in pitch (decrease) is not significant. However, as the % pitch decreases, any change becomes more serious. As indicated in 2.084 a 1% change in T.P.I. results in a .48% change in lpw. A 10% decrease in pitch would cause an approx. 40% decrease in life.

6.1.4 Low Fill Pressure.

The life of a lamp varies directly with fill pressure for two reasons. The filament evaporation increases with lower pressure and also because the filament temperature increases due to lack of cooling by the fill gas.

6.1.5 FILL GAS MIXTURE.

The thermal conducticity of the fill gas varies depending on pressure and the chemistry of the fill gas. The lighter the fill gas the better the thermal conduction and the cooler the filament. A lamp designed for a Kr fill would have short life if filled with nitrogen or a mixture of KR + N_2 and N_2 was more than a few percent of the mixture.

6.1.6 Sagging.

When a horizontal mounted filament (C-6 or CC-6) sags, the bottom of the coil opens up and the top may close. The result is a decrease in T.P.I. on top of the coil and hot spots develop accordingly.

When a vertical mount filament (C-8 or CC-8) sags, the turns pile up at the bottom. The result is a localized T.P.I. shift and the filament fails at the bottom of the coil due to excessive temperatures.

6.2 AC vs. DC Lamp Current

At the end of the seasoning period, the luminous output of the lamp is the highest it is ever going to be. Right after seasoning, etching or facet formation begins. Vacuum lamps and gas-filled lamps are both subject to AC or DC etching. For very high lpw lamps, evaporation is rapid enough to prevent facet formation. Most common lamp types will develop facets during life. Vacuum and gas filled lamp etching is similar. DC etching in low current lamps results in notches more than half way through the wire

6.2 AC VS. DC LAMP CURRENT - (CONTD.)

diameter when the wire is one mil (25μ) diameter or less. The result is, life of DC lamps with one mil wire or less, is only a fraction of the life of the same lamp on AC. Life then, is extended by AC current for low current lamps. On the other hand, heavy filaments have longer life on DC current because DC etching is more rapid than AC etching and etching or facet formation increases the surface and cools the filament. Full AC etching is as rough as full scale DC etching. The life and maintenance of high current lamps burned on DC is significantly better than AC lamps. When there is a choice, AC is used for low current lamps and DC for high current lamps.

There is evidence that facet formation increases with tungsten additives. The more pure the tungsten the more resistant to either AC or DC etching. Tungsten Rhenium wire is more resistant to facet formation than thoriated tungsten wire. The thermoelectric properties of tungsten lamp wire is also a factor in facet formation. In AC lamps, a steep temperature gradiant near a support touching a hot filament appears to cause DC etching on both sides of the support even though the lamp current is AC. See Figure 6.2.1.

The thermoelectric effect seems to superimpose a DC current in these areas which causes the notching. Steep temperature gradiants are to be avoided for maximum lamp performance. Supports should either be a big heat sink like leads or not touched at all.

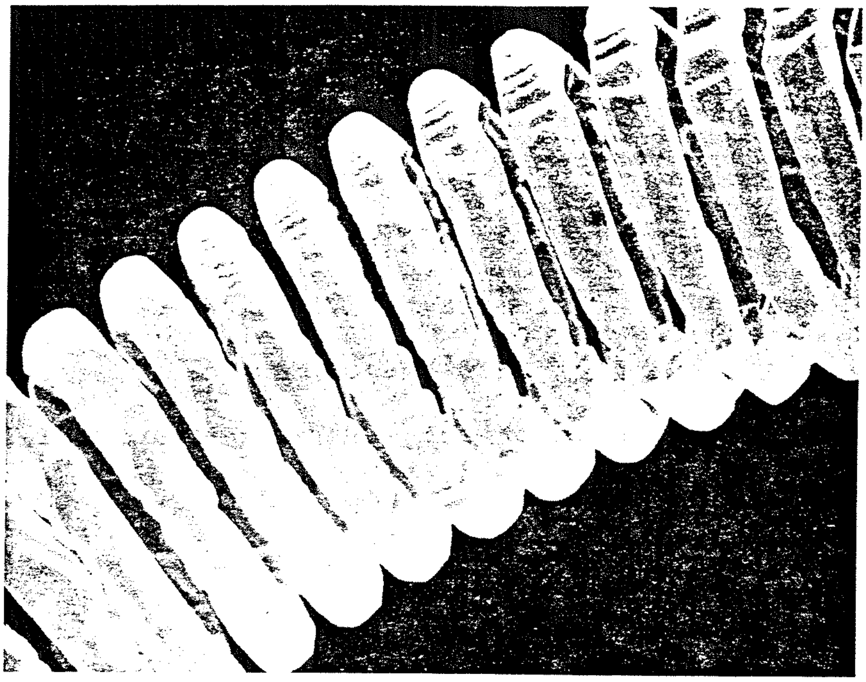
6.2 AC VS. DC LAMP CURRENT - (CONTD.)

If supports are necessary, the filament can be designed for them by having pull turns in supports or other geometries. The formation of facets and location of final crystal boundaries are caused and altered by more than just the current and coil temperature. The tension stresses on outside of turns and compression on inside of turns have a visible effect on the geometry of the facets. On single coils, facets develop on the inside and outside of the coil. On coiled coil filaments the facets appear mainly on the inside of the coil. Lamps which fail due to notching do not develop hot spots, failure is usually mechanical due to the weak and brittle structure.

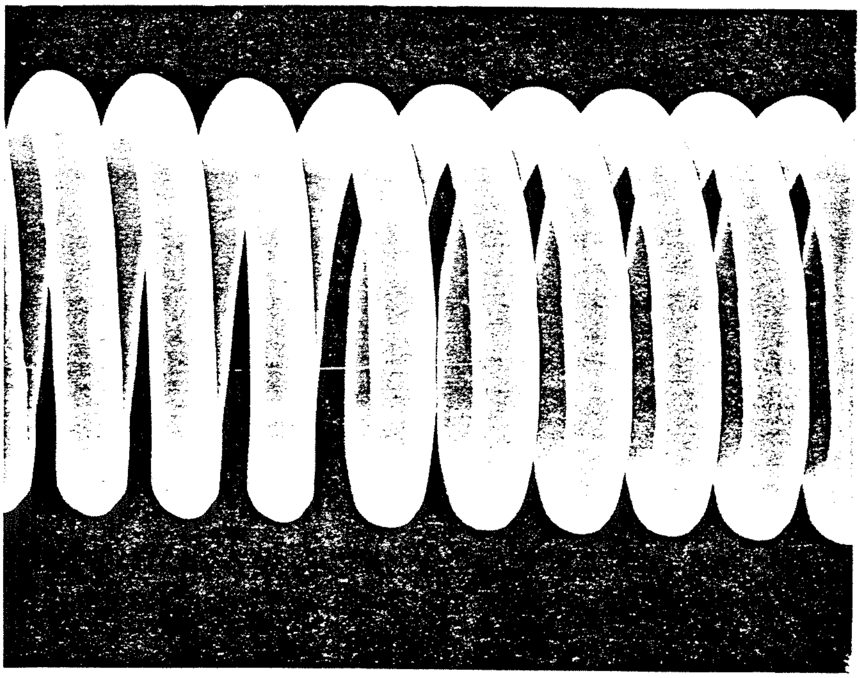
6.3 The Mass of the Filament

A hot spot can be caused by a thin spot in the filament wire. The thin spot can be a result of wire drawing or being stretched locally during filament winding. An out of round wire or a wire which is scored or partially fractured can also cause a localized hot spot. The effect of the wrong size filament wire is indicated in 2.5. The wrong size mandrel can result in a hot running coil because the filament length is too short. When the radiating area of the coil is too small, the coil temperature must be raised to get more lumens per unit area. The result is higher coil temperature for the same measured lpw as a correctly designed filament.

B. NS Wire Vacuum Lamp Burned 1000 Hours A.C.



Turns near Support



Turns between Leads and Supports

Figure 6.2.1

6.3 THE MASS OF THE FILAMENT - (CONTD.)

Studies over the years have shown that a straight wire burned in vacuum loses 18-32 percent of its weight before it fails. The range of weight loss means that the quality of the wire is a factor. The smoother the wire the more resistant to hot spots and therefore the higher weight loss and longer life before failure. Production lamp wire results in lamp failure when 18-20 percent of filament mass has evaporated. The % loss at failure decreases with single coiling and decreases further with coil coiled lamps.

6.4 Arcing

The concern here is arcing before end of normal life. Arcs are caused by several factors.

6.4.1 Fill Gas Mixture

Most fill gases require a few % of N_2 fill to prevent arcs. The N_2 is usually a minimum because N_2 tends to shorten life by increasing W evaporation. Careful control over the fill mixture is required.

6.4.2 Wrong Burning Position

Some lamps are designed to only burn in one position, usually base down. This is because the greatest voltage potential is across the leads and when the lamp is burned base up the hot gases convected from the filament set up a combination which results in an arc.

6.4.3 FILAMENT VOLTAGE

When a lamp is energized for the first time, arcing can occur if the initial light up voltage is too high. The filament wire is not pure tungsten and is initially fibrous. During the changeover from fibrous to crystal structure, materials are boiled out and vaporized. These materials ionize and arcing occurs.

6.4.4 Contaminated Filament

During the process of wire drawing and filament winding, lubricants etc., are used. These materials, if left on the finished coil, boil off at a rapid rate during initial light up. A contaminated coil may arc at 80 volts, for example, whereas a clean coil may not arc until 180 volts. The process of flashing by stepped voltage is largely to compensate for varying degrees of coil contamination. The increase in lumens and decrease in current during aging is due to the same mechanism. Some special photocopy lamp coils are made of special clean and smooth wire to prevent current changes during aging or lamp operation.

6.4.5 Contaminated Support Wire

Contaminated moly support wire results in a delayed arc. The moly support draws no current and only gets hot by conduction of heat from the filament and fill gas. The arc will not occur on machine flashing because lamp is not on long enough. Clean moly wire must be used for supports. Doped moly wire is used to prevent the moly from getting brittle and breaking during lamp operation due to shock and vibration.

6.4.6. CONDENSED W ON GLASS BUTTON

On some lamp types, a glass button - an extended part of the stem press which has been flattened - is used to insulate support wires. At times, especially when burned base up, W condenses on the glass button and electrically connects the supports or leads to the full voltage potential. This usually results in an arc between leads which leaves the filament intact except where it was burned off at both ends (tails).

6.5 The Environment Surrounding the Filament

All lamps turn black to varying degrees during life. A vacuum lamp gradually gets black all over. A gas-filled lamp gradually gets black in area directly above the filament. The black is caused by evaporated and recondensed tungsten from the filament.

However, a contaminated vacuum or fill gas will cause the lamp to get black and fail early in life. There are at least four sources of gas within the lamp bulb.

6.5.1 Residual Gas

Since the vacuum pumps cannot remove all the gas in a bulb, there is a residual gas in a vacuum lamp or mixed with the fill gas in a gas-filled lamp. The residual gas may be air or flush gas.

6.5.2 Gas From the Filament

The quantity of gas given off by a filament varies with the cleanliness of the filament. The gas evolved may be from 3 to 10 times the volume of the filament. The gas usually consists of CO, H_2 and CO_2.

6.5.3 GAS FROM LEADS AND SUPPORTS

In many lamps, the leads and supports become hot and there are often clear indications that gas is evolved. The following table shows the gas evolution of nickel depending on processing.

GAS EVOLUTION FROM NICKEL SAMPLES (Arbitrary units)

Sample	Total	H_2	H_2O	$CO+N_2$	CO_2
Only degreased	3000	1050	340	2300	570
H_2 fired, stored dry	270	50	15	45	50
H_2 fired, touched by hand	6000	1800	348	*	1400
H_2 fired, touched by hand and degreased	590	220	15	110	70
H_2 fired, touched by rubber cots	800	300	250	300	110
H_2 fired, touched by freshly cleaned cotton gloves	1150	550	60	800	200
Air fired	1100	62	110	*	380
Acid cleaned	290	120	*	*	55

6.5.4. GAS FROM THE BULB

Glasses contain occluded and adsorbed gasses and vapours, especially water vapour. Besides water, also hydrogen, nitrogen, oxygen and carbon dioxide are contained in and on the glass.

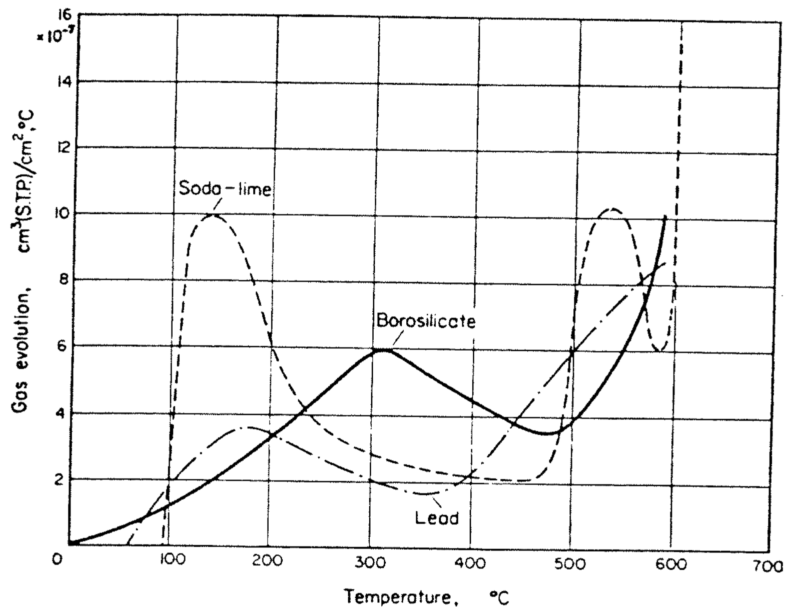


Figure 6.5.4.1 The evolution of gas from various glasses as a function of the temperature (after Ardenne, Espe, Roth)

6.5.5. EFFECT PRODUCED IN LAMPS BY VARIOUS GASES

Hydrogen

Dry H_2 in lamps will not cause blackening of the bulb at any pressure in GLS lamps, unless oxides are present to be reduced, forming water vapor.

Oxygen

At all temperatures above 1000°C this gas reacts with tungsten to form the yellow oxide WO_3, no matter how low the pressure of the oxygen may be. The oxide distills off the filament and deposits on the bulb, but owing to its light color the deposit is invisible when the amount of oxygen is less than 100 to 200 cu. mm. Oxygen, therefore, never produces blackening of the bulb. When partial pressure of O_2 is very low (See 5.7.1).

Nitrogen

There are three ways in which this gas cleans up in a lamp, each being an exceptionally interesting phenomenon in itself. With voltages above 40 volts and pressures above 0.001 mm the nitrogen cleans up provided the filament temperature exceeds 2000°K. It attacks the negative end of the filament, producing a brown deposit of tungsten nitride, WN_2 on the bulb.

Carbon Monoxide

This gas behaves almost exactly like nitrogen. At low pressures it never produces perceptible blackening of the bulb, although at higher pressures it may slowly give a slight

CARBON MONOXIDE - (CONTD.)

deposit of carbon under certain conditions. The results, however, clearly indicated that traces of carbon monoxide such as might exist in lamps, could not be responsible for the blackening.

Carbon Dioxide

This gas attacks the filament and produces carbon monoxide and an oxide of tungsten, without producing any perceptible blackening.

Methane

This gas is decomposed, producing hydrogen, while the carbon is taken up by the filament, and is indicated by the resulting change in the electrical resistance. At very high temperatures the carbon distills out of the filament again. No visible blackening of the bulb occurs,

Chlorine, Bromine, Iodine, Sulfur, Phosphorus, Phosphine, Hydrochloric Acid, Mercury Vapor. None of these gases will produce blackening in GLS lamps.

Water Vapor

The fact that lamps exhausted at low temperature (say 100 to 200 deg.) blacken so rapidly during life, together with the fact that water vapor is the principal gas removed from the bulb by heating, indicate that the water vapor is responsible for the blackening and short life under these conditions.

6.5.5 WATER VAPOR - (CONTD.)

It is rather surprising that water vapor should have such a marked effect when either of its constituents, hydrogen or oxygen, acting alone, produces no blackening.

The explanation of the behavior of the water vapor is as follows:

The water vapor coming into contact with the filament is decomposed, the oxygen combining with the tungsten and the hydrogen being evolved. The oxide distills to the bulb, where it is subsequently reduced to metallic tungsten by atomic hydrogen given off by the filament, water vapor being simultaneously produced. The action can thus repeat itself indefinitely with a limited quantity of water vapor.

Another experiment demonstrated that even the yellow oxide, WO_3, could be reduced at room temperature by atomic hydrogen. A filament was heated in a well exhausted bulb containing a low pressure of oxygen; this gave an invisible deposit of the yellow oxide on the bulb. The remaining oxygen was pumped out and dry hydrogen was admitted. The filament was now lighted to a temperature (2000deg. K) so low that it could not possibly produce blackening under ordinary conditions. In a short time the bulb became distinctly dark, thus indicating a reduction of the oxide by the active hydrogen.

6.6 BULB BLACKENING AND THE WATER VAPOR CYCLE

Bulb blackening in micro-miniature, subminiature, miniature, and GLS lamps vacuum or gas filled is caused by deposition of tungsten on the bulb wall.

6.6.1 Water Vapor Cycle

The water cycle causes early blackening and short life. In vacuum lamps, the water cycle is seen as an increase in current, decrease in filament temperature, early blackening and short life. Gassy lamps usually will fail due to a water cycle. The tungsten deposit in vacuum lamps will be above the filament or on the point closest to the filament in those cases where water vapor was evolved by bulb over-heating locally.

In gas filled lamps, the water vapor cycle is first indicated by darkening of the leads and clamps. The water cycle transfers tungsten from hot areas to cold areas. That is, the evaporated tungsten oxide will condense at any point that is cool enough. When the water cycle has started, the action can be observed on the filament. The water cycle attacks and removes tungsten from the filament turns near the end of the coil, usually two to five turns from the clamps depending on lamp efficacy and coil geometry. The cooler turns next to the clamp may grow in size while the attacked turn gets thin. The attack point will move as the turn gets hot due to thinning. The tungsten deposited on cooler turns will be on the side facing the thin turn. Actual filament failure

6.6.1 WATER VAPOR CYCLE - (CONTD.)

can be due to any one of several reasons relating to the thin turn or turns - shorted turns, fusing, mechanical break, high temperature evaporation, sag, etc.

THE MAJOR CAUSE OF ALL SHORT LIFE LAMPS IS THE WATER VAPOR CYCLE.

Water vapor cycle is obscured in high force life test lamps because the filament evaporation rate is so high it becomes a greater tungsten transport than the water cycle. Therefore, force life test is not a measure of lamp quality regarding presence of water vapor or failure due to water vapor. A Hot bulb test at normal filament voltage is a more reliable indicator.

6.6.2 Lamp Blackening in Subminiature Vacuum Lamps

There are a few special causes of blackening in microminiature and subminiature vacuum lamps.

1. Moly Contamination

Small filament wire has a large surface to mass ratio. When sintered on moly mandrels during coil manufacturing, the tungsten coil picks up some moly from the mandrel. The higher the sintering temperature the greater the moly contamination.

When the lamp is completed and life tested, the moly evaporates and condenses on the bulb. Moly melts and vaporizes at least $800^{o}C$ lower than tungsten.

2. Tungsten Carbide

Filaments contaminated with carbon will distort and squirm and cause blackening by deposition of carbon and also tungsten carbide.

6.6.2 LAMP BLACKENING IN SUBMINIATURE VACUUM LAMPS

Carbon contamination results in a resistivity change which will change lamp characteristics.

6.7 Elimination of Water Vapor

Hydrogen or oxygen alone in a lamp will not cause the destructive water vapor cycle. However, H_2 and O_2 together in a lamp as separate gases or as H_2O vapor will cause the water cycle. There are many sources of these gases - the fill gas, the filament, the lamp leads and supports and, most of all, the glass bulb and stem parts.

6.7.1 Potential Sources of Water in Glass

The amounts of residual gas, together with all the gas that is given off by the filament and its supports, are quite insignificant compared with the amount of gas on the inner surface of the bulb.

1. Water adsorbed on the surface of the glass.
2. Water included in a hydrated layer at the surface. Old glass (008 lime glass) can contain 5 times as much water as freshly drawn glass.
3. The third source of water is that contained within the bulk of the glass. Various degrees of heat will release water from all three sources. At lower (100-300°C) temperatures the water evolved from glass is primarily from the surface. This water can be in two forms (a) as an adsorbed layer on the surface or (b) in the form of a complex hydrate on the surface.

6.7.1 POTENTIAL SOURCES OF WATER IN GLASS - (CONTD.)

The adsorbed moisture is the most easily removed and can be exhausted relatively quickly if the glass is maintained at a sufficiently elevated temperature. The water in the surface hydrates is much more tenaceous. Most data in the literature are taken over minutes or hours rather than the seconds available for evacuating incandescent lamps, so the kinetics of the breakdown of this layer are not known. Nevertheless, it seems that prudence would dictate that only fresh soda-lime glass be used for vacuum applications, particularly in cases where the device may run at elevated temperatures. If fresh glass is not available, the hydrate layer may be stripped by cleaning the glass in 1% HF solution for 3-4 minutes followed by a water rinse.

6.8 GENERAL RULES FOR DEGASSING LAMP MATERIALS

6.8.1 Metals

The pretreatment includes degreasing, cleaning, firing, storing, handling and mounting. The influence of these treatments on gas evolution from nickel samples when heated to 850°C is shown in Table 6.8.1.1.

GAS EVOLUTION FROM NICKEL SAMPLES (Arbitrary units)

Sample	Total	H_2	H_2O	$CO + N_2$	CO_2
Only degreased	3000	1050	340	2300	570
H_2 fired, stored dry	270	50	15	45	50
H_2 fired, touched by hand	6000	1800	348	*	1400
H_2 fired, touched by hand and degreased	590	220	15	110	70
H_2 fired, touched by rubber cots	800	300	250	300	110
H_2 fired, touched by freshly cleaned cotton gloves	1150	550	60	800	200
Air fired	1100	62	110	*	380
Acid cleaned	290	120	*	*	55

TABLE 6.8.1.1

Occluded or adsorbed gases on metals can be removed effectively by heating the metal in vacuum or in a gas which does not react with the metal. Hydrogen particularly is used because it simultaneously reduces the existing oxides and later can be driven out easily from the metal due to its higher permeation.

6.8.1 GENERAL RULES FOR DEGASSING LAMP MATERIALS

For a successful degassing the temperature of metal parts and enclosures is raised to: 400-500°C for copper and aluminum and to 950°C for iron, nickel and steel components. It is obvious that when steel containers sealed with copper or aluminum gaskets are to be degassed, the latter materials determine the upper temperature limit.

6.8.2 Glass

Generally the gas evolution from glasses increases with increasing alkali content. Thus lead glasses have a lower gas evolution (especially water) than the various other glasses. The gas content and evolution is also influenced by some other factors including age, atmospheric influence during storage and method of cleaning. It should be pointed out that the diffusion of water vapour from the glass into the evacuated space is a reversible process. For a given glass at an arbitrary temperature there is an equilibrium partial pressure of water vapour. If the partial pressure of water vapour in the surrounding space is greater than this equilibrium pressure, water diffuses back into the glass; if the partial pressure is less, water diffuses out. Therefore, for water degassing, heating in dry atmosphere has the same effect as heating in vacuum.

As a general rule the degassing temperature of glasses is about 20-50°C below the strain point of the glass, i.e., about 400°C for lead glasses, about 500°C for soda-lime and about 600°C for borosilicates.

6.8.3 RUBBERS AND PLASTICS

Rubbers evolve a great amount of gases, especially when they are new and untreated or have the form of pipes (containing higher quantities of plasticizers. The vapour pressure of natural rubber is 10^{-3} torr at $20^{\circ}C$, decreasing to 10^{-5}-10^{-6} torr at temperatures of -20 to $-40^{\circ}C$. Silicone rubbers have lower vapour pressures, and special vacuum rubbers (e.g. Hycar, Neoprene) have even lower ones (1.10^{-4} torr at $20^{\circ}C$).

In order to obtain lower outgassing rates the rubber must be cleaned with a solution of KOH (20 per cent) at $70^{\circ}C$ with subsequent washing with distilled water and drying with clean air, and/or degassing in vacuum at $70^{\circ}C$ for 4-5 hours. Using clean rubber the lowest pressure range attainable in the system is between 10^{-5} torr and 10^{-6} torr.

Plastics have (like rubbers) high outgassing rates. Hence they are generally not included in vacuum systems for pressures lower than 10^{-4} torr. Exceptions to this rule are the polytetrafluorethylenes (Teflon, etc.) and the polytrifluorochloroethylenes.

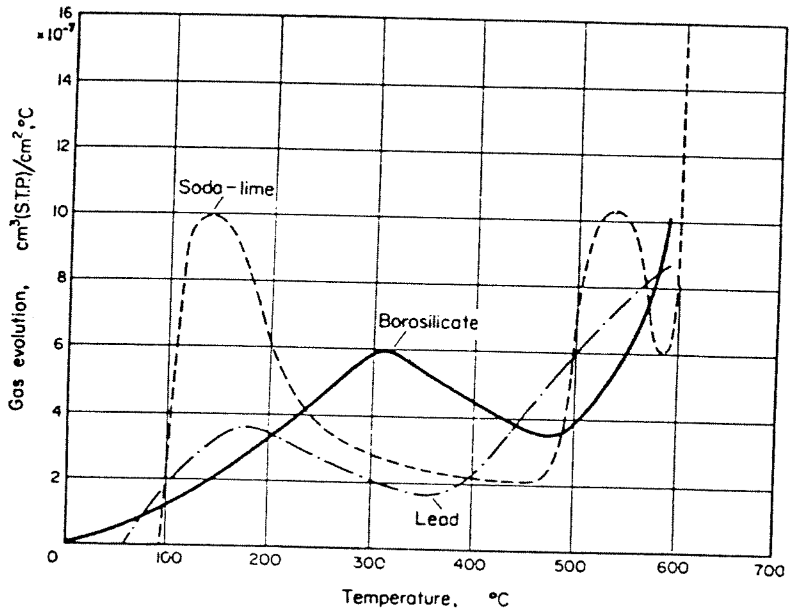
FIGURE 6.8.3.1 shows the outgassing rate of some common materials.

Material*	Vapour pressure at 20 °C (torr)	Outgassing rate (after 3 hr pumping) (lusec/cm^2)
Neoprene rubber (Hycar, Perbunan, or Nitrile)	4×10^{-3}	1×10^{-3}–3×10^{-3}
As before but cleaned	1×10^{-4}	2×10^{-4}–3×10^{-4}
Silicone rubber	2×10^{-4}	2×10^{-4}–7×10^{-3}
Teflon, Fluon	3×10^{-5}	4×10^{-5}–3×10^{-4}
Hostaflon, Kel-F Viton	—	2×10^{-5}–6×10^{-5}
Plexiglass, Perspex, Lucite	1–2×10^{-4}	2×10^{-5}–4×10^{-4}
Polyethylene	5×10^{-5}	1×10^{-4}–3×10^{-4}
Polystyrene	4×10^{-5}	2×10^{-4}–9×10^{-4}
PVC, Astralon, Tygon	2–6×10^{-3}	4×10^{-4}–2×10^{-3}
Araldite	—	2×10^{-5}–6×10^{-5}

Figure 6.8.3.1

LAMP FAILURE MECHANISMS

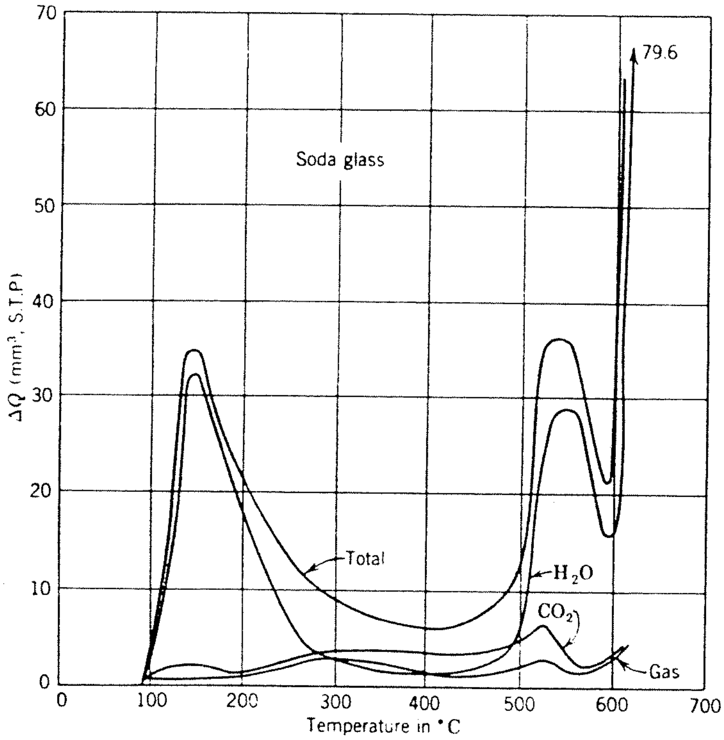
FIGURE 6.7.2.1 shows the total evolution of gas from common lamp glass as a function of temperature.



The evolution of gas from various glasses as a function of the temperature
Ardenne , Espe , Roth

Figure 6.7.2.1

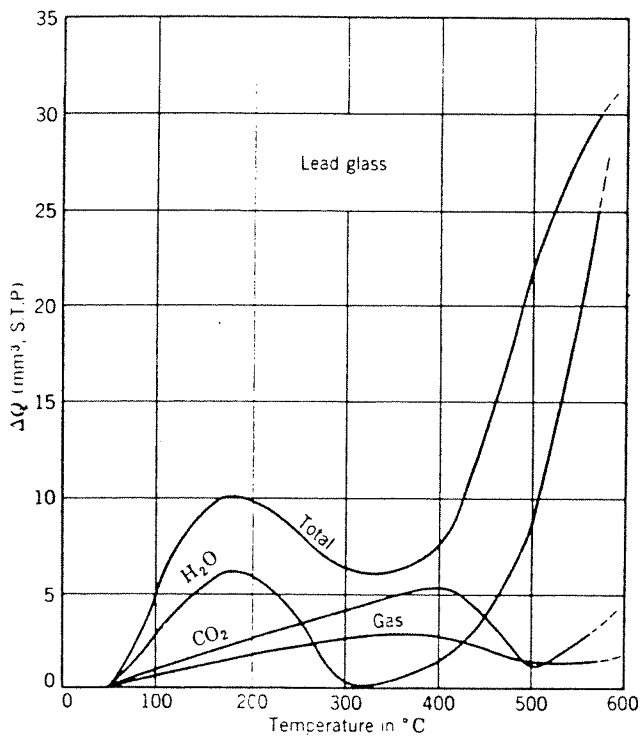
FIGURE 6.7.2.2 shows the breakdown of the gases evolved from soda-lime (008) lamp bulb glass.



Evolution of gas from soda glass (Sherwood).

Figure 6.7.2.2

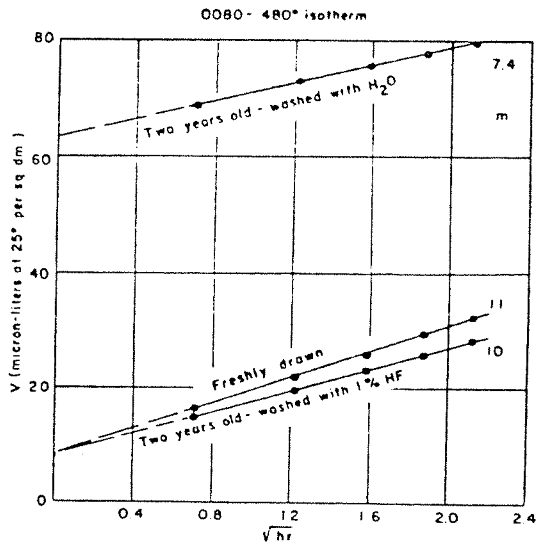
FIGURE 6.7.2.3 shows the breakdown of the gases evolved from lead (001) glass as a function of temperature.



Evolution of gas from ordinary lead glass (Sherwood).

Figure 6.7.2.3

FIGURE 6.7.2.4 shows the comparison of gas evolution (outgassing) of new and old glass at a bake out temperature of 480°C.



Comparison of old and new No. 0080 glass and old No. 0080 glass washed with 1% HF at a bake-out temperature of 480°C. (*V vs* square root of bake-out time.)

Figure 6.7.2.4

6.9 REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

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5. Behavior of Incandescent Tungsten Tilaments During Life by B. A. Moys, GEC Journal of Science and Technology Vol. 40, No. 1, 1973.

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7. The Effect of Hot Spot Length on Behavior of Straight-Wire Incandescent Filaments by Craig Baker Journal of IES, April, 1975, pages 163 - 170.

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9. Incandescent Lamp Failure Mechanism by Warren Anderson and Ed Passmore, GTE Sylvania, Journal of IES, October, 1975, Pages 31 - 36.

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12. Life Prediction of Tungsten Filaments in Incandescent Lamps by R. Raj and G. W. King, Metallurgical Transaction Volume 9A, July, 1978.

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17. The Collected Works of Irving Langmuir, Pergamon Press, Volume II.

18. Vacuum Sealing Techniques by A. Roth, Pergamon Press, 44-01 21st St., Long Island City, New York, 11101.

19. A Study of Glass Outgassing by J. W. Smith, GTE Sylvania, Danvers, Mass. 01915.

20. Outgassing of Glass by B. Johnson Todd, Journal of Applied Physics, Volume 26, No. 10 (1238-1243), October, 1955 and Volume 27, No. 10, Page 1209, October, 1956.

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21. Scientific Foundations of Vacuum Technique by Saul Duskman, John Wiley & Son, Inc.

22. Langmuir, I., J. Am. Chem, Soc. 38, 2221 (1916).

23. Langmuir, I., U. S. Patent, 1,273,629 (1918).

24. Sherwood, R. G., (a) Phys. Rev., 12, 6, 448 (1918)
(b) J. Am. Chem. Soc. 1G45, (1918)

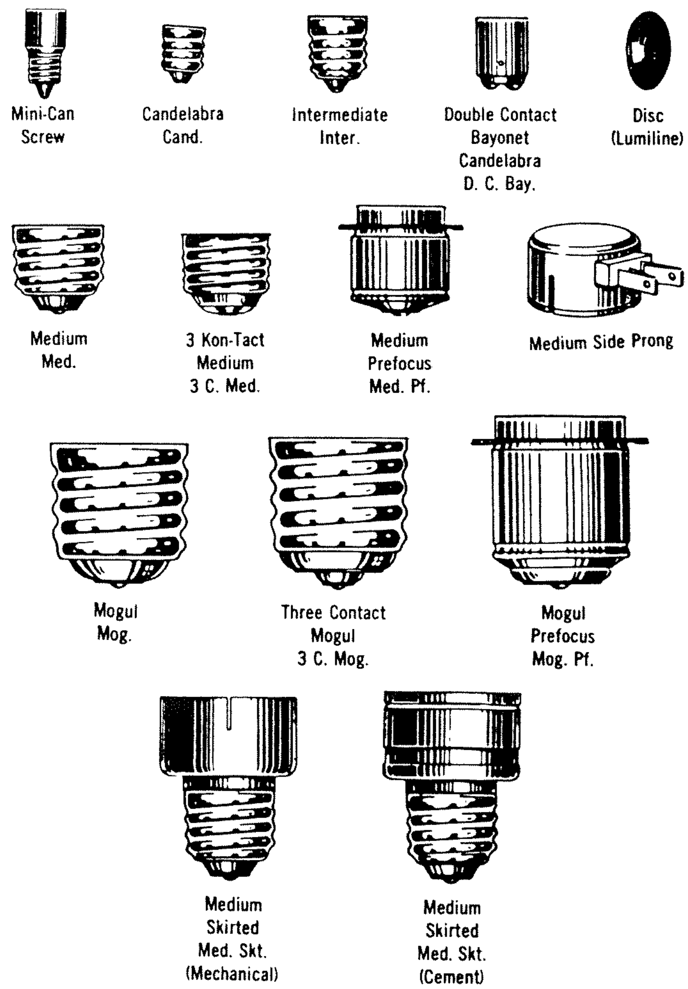
LAMP BASES

7.0 The base of an incandescent lamp performs two very important functions --

(1) it holds the lamp firmly in the socket in the electrical circuit and

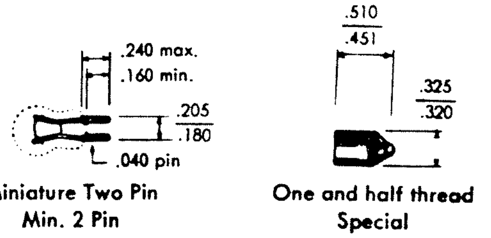
(2) it conducts the electricity from the circuit to the lead-in wires of the lamp. For a majority of applications lamps are furnished with one of the various sizes of screw bases. Standard screw bases have a right hand thread, but the medium screw base may be supplied with a left hand thread if required.

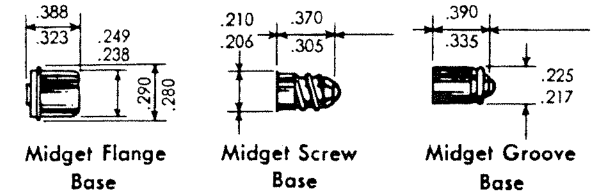
7.1 TYPES OF BASES

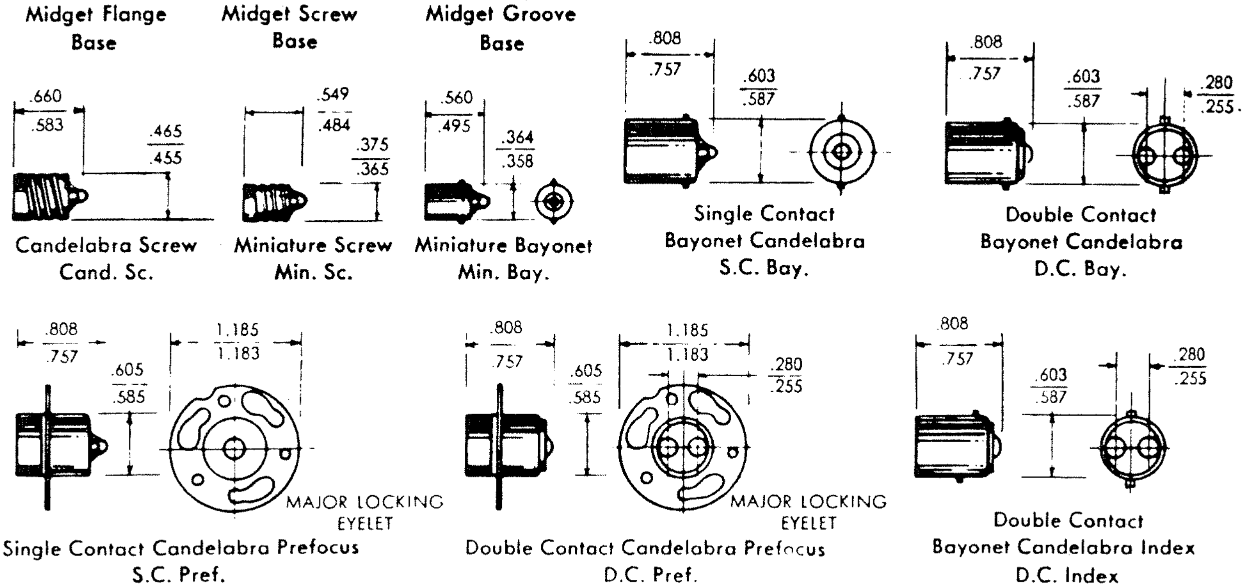


LAMP BASES

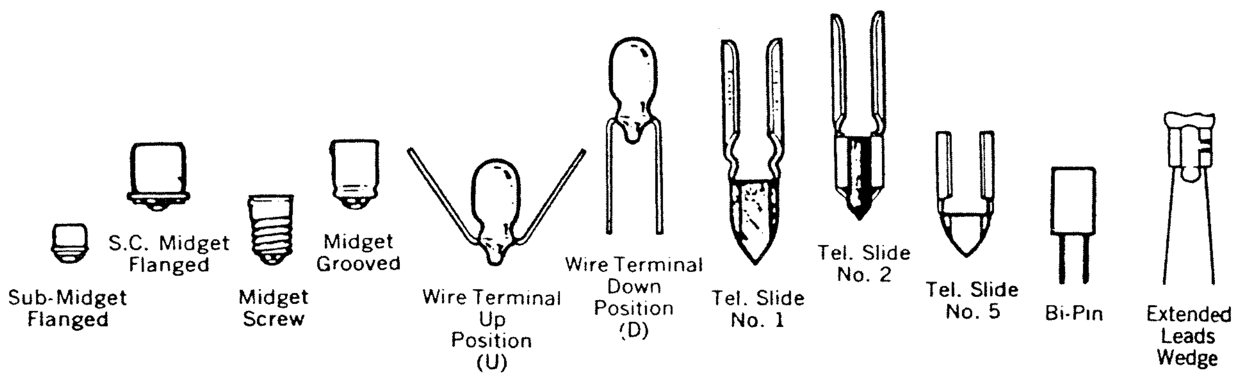
The dimensions of the line drawings of the bases indicate the maximum and minimum length and diameter in thousandths-of-an-inch, (SAE and industry standards) for guidance in socket and/or receptacle design.







Miniature Lamps



Sub-Miniature Lamps

LAMP BASES

VARIOUS INCANDESCENT LAMP BASES

Base Type	Typical Lamp Using This Base
Mini-Can Screw	250 Watt, T-4, Tungsten Halogen
Candelabra	15 Watt, F-10, Decorative
Intermediate	10 Watt, S-11, Sign
Medium	100 Watt, A-19, Standard
Medium Skirted — (cement)	250 Watt, G-30, Infrared
Medium Skirted Mechanical (1 piece)	150 Watt, PAR-38, Reflector
Three Kon-Tact Medium	50-100-150 Watt, A-21, Three-lite
Mogul	1000 Watt, PS-52, Standard
Three Contact Mogul	100-200-300 Watt, PS-25, Indirect Three-lite
Medium Prefocus	500 Watt, T-10, Projection
Mogul Prefocus	1000 Watt, G-40, Spotlight
Double Contact Bayonet Candelabra	25 Watt, T-8, Home Appliance
Disc	40 Watt, T-8, Lumiline
Medium Side Prong	150 Watt, PAR-38, Reflector

7.1.1 Screw Bases

The candelabra, intermediate, medium and mogul screw bases for most general lighting service lamps are cemented to the glass bulb. In higher wattage lamps (generally those over 500 watts) which submit the cement to higher temperatures, even the best standard basing cement may lose some of its strength and permit the base to loosen. To insure greater strength and durability for some street lamps and for higher-wattage general lighting service lamps and floodlights, a combination of cements designed for high temperatures are used.

7.1.1 SCREW BASES - (CONTD.)

The 300 Watt, PS-35 lamp employs a mogul base as standard equipment, but is also furnished with a medium skirted base that is cemented to the bulb.

Another base which is attached to the glass bulb without cement is the mogul clamp base. It is fastened to the bulb by an asbestos lined clamp which grips the bulb firmly.

7.1.2 Prefocus Base

When it is necessary that a light source be very exactly placed with respect to a lens or reflector, the medium or mogul prefocus base is used to insure the proper location of the filament. The prefocus base consists essentially of an inner shell which is attached to the bulb with cement and an outer brass shell which is set in the proper position to insure an exact light center length. After positioning, the parts are soldered together.

7.1.3 Medium Skirted Base

Sylvania's PAR-38 Reflector lamp has a medium skirted base of only one piece which is crimped near the top to hold the glass bulb.

7.1.4 Bayonet Base

The bayonet base has two pins, placed on opposite sides, to slide into slots in the socket. These hold the lamp firmly and prevent it from becoming loose enough to break the electrical connections or to fall out. Home Appliance lamps are supplied with double contact bayonet bases to keep them tightly in the sockets on

7.1.4 BAYONET BASE - (CONTD.)

sewing machines or vacuum cleaners. The double contact bayonet medium base is more or less standard in England, but is seldom used in this country.

7.1.5 Three Kon-Tact Base

The three Kon-Tact Base is best known for its application on the 50-100-150 watt, A-21 lamp. A tapered ring contact, set at an angle, provides positive contact under pressure with contact elements of the socket. This lamp has two filaments, which may be operated separately or together to furnish three levels of illumination. The base consists of an outer screw shell, a ring contact and a center contact. One end of the low wattage filament is connected to the ring contact, one end of the high wattage filament to the center contact and the other ends of the two filaments to the common lead attached to the base shell.

7.1.6 Disc Base

The lumiline lamp is unique in that it utilizes two disc bases at opposite ends of the bulb with each one connected to the filament.

7.1.7 Recessed Single Contact Base

Recessed Single and Rectangular Recessed Single Contact bases with special ceramic, instead of metal, are used for double based Tungsten Halogen lamps.

7.1.8 MINI-CAN SCREW BASE

On the single-based Tungsten Halogen lamp the base type commonly used is the Mini-Can Screw.

7.2 Current Carrying Capacity of Bases

Current carrying capacity must be considered when selecting a base. Maximum safe current for the medium base is 25 amperes. The mogul base will carry 35 amperes. Although not a problem at standard voltage (120 volts), this limiting factor is important for low voltage application such as swimming pool lamps (12 volt).

7.3 Base Material

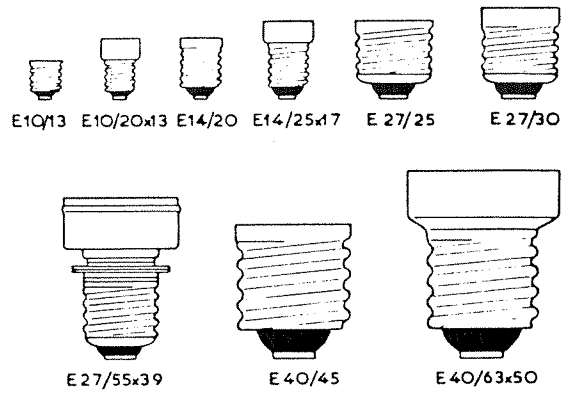
For many years, brass was the major base material and is still used for many types.

Automotive lamps and other lamps used in exterior application are usually brass or nickel-plated brass. Most high volume lamps for interior application (homes for example) have aluminum bases. Aluminum is a better conductor of electricity and is less expensive than brass. Aluminum screw bases are coated with a special lubricant (sperm oil or a suitable substitute) which does not interfere with the electrical contact.

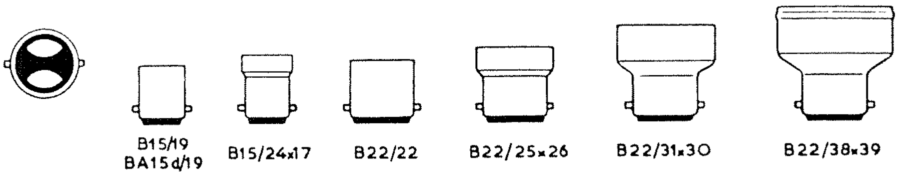
LAMP BASES

7.002 European Bases

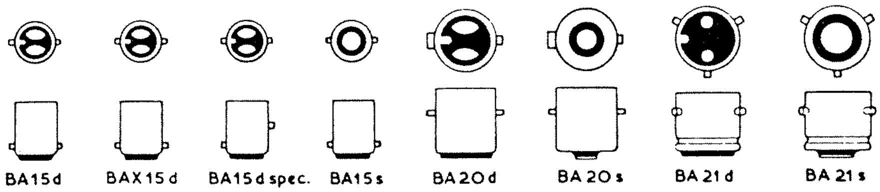
SCREW BASES



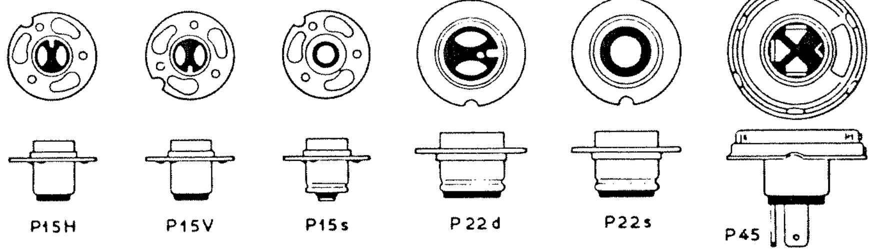
BAYONET BASES



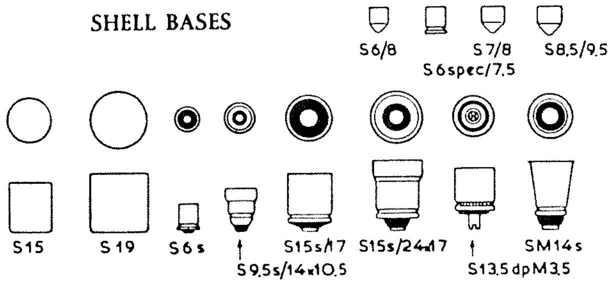
MOTORCAR BAYONET BASES



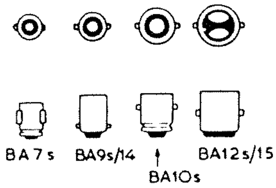
PREFOCUS BASES



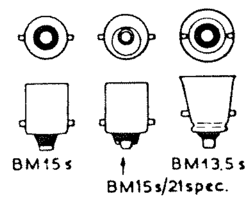
SHELL BASES



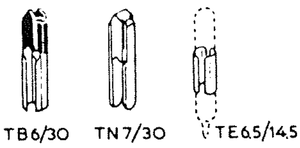
MINIATURE BAYONET BASES



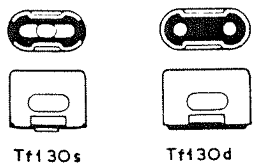
BAYONET BASES FOR MINERS LAMPS



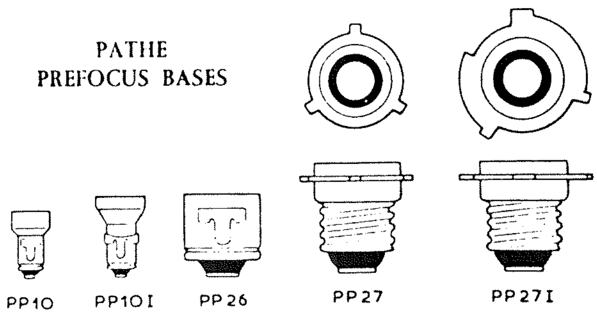
SIDE CONTACT BASES



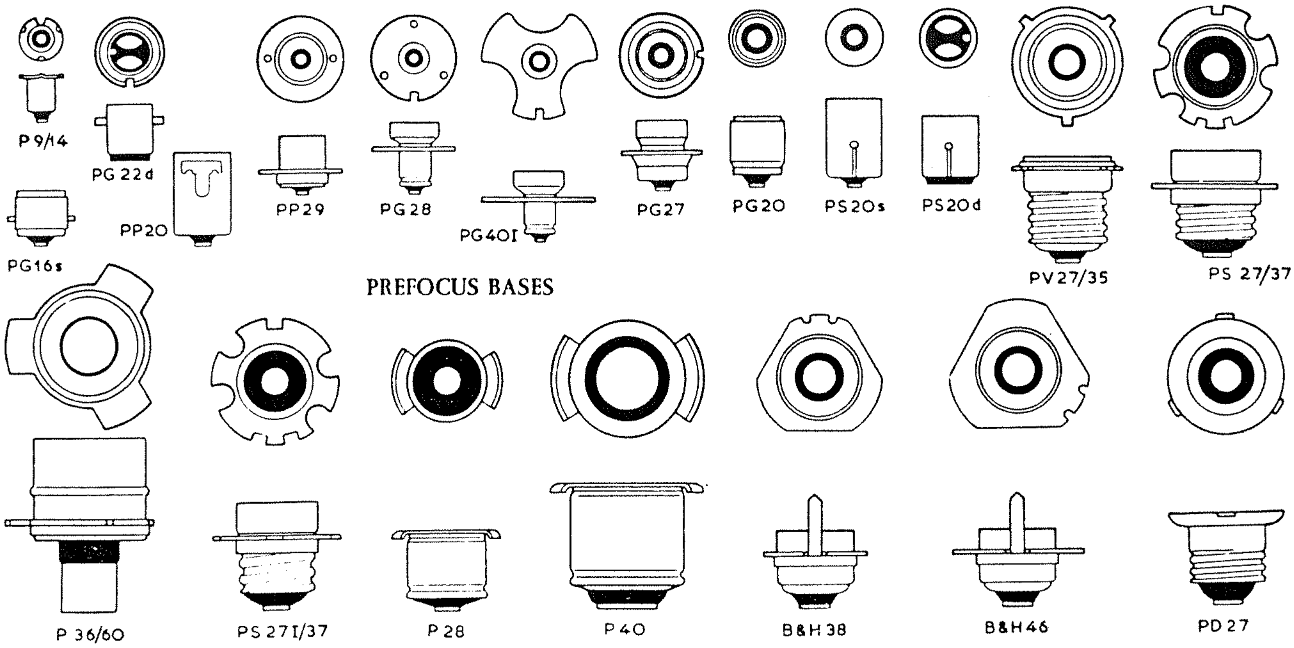
PATHE PREFOCUS BASES



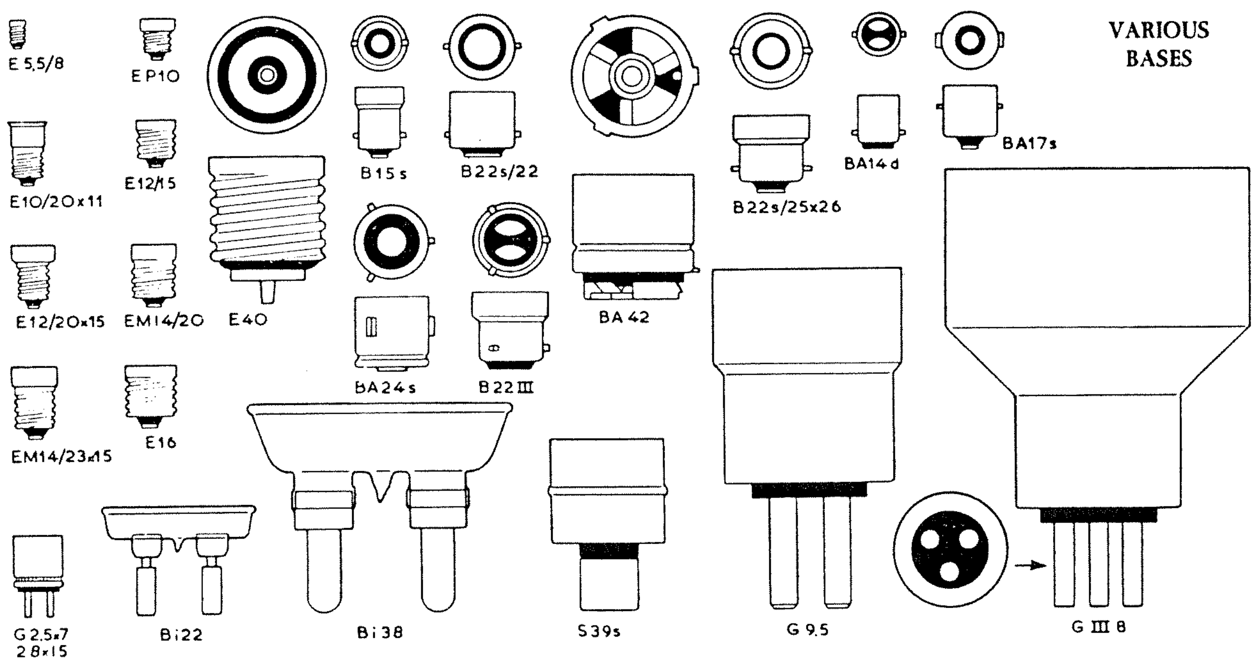
TELEPHONE BASES



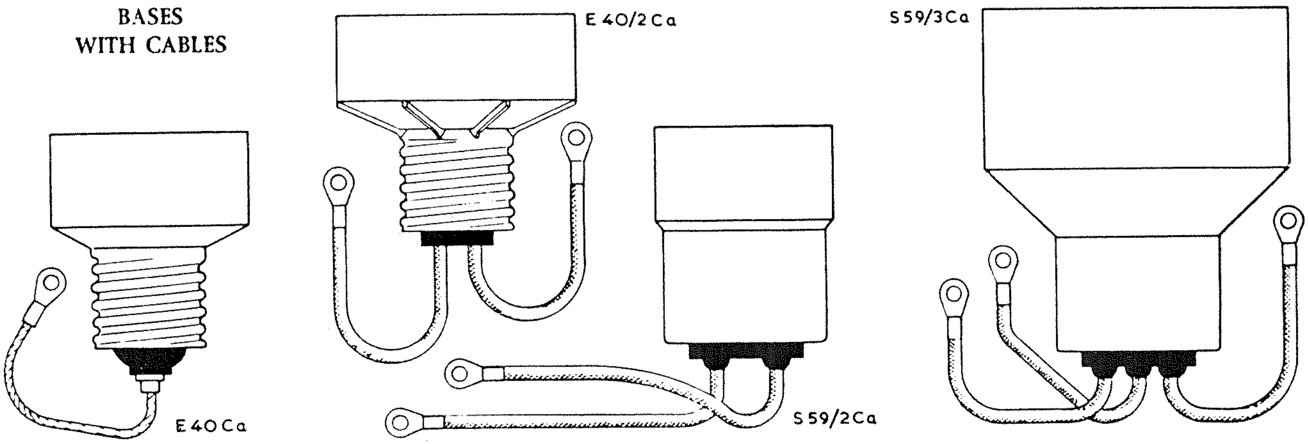
PREFOCUS BASES



VARIOUS BASES

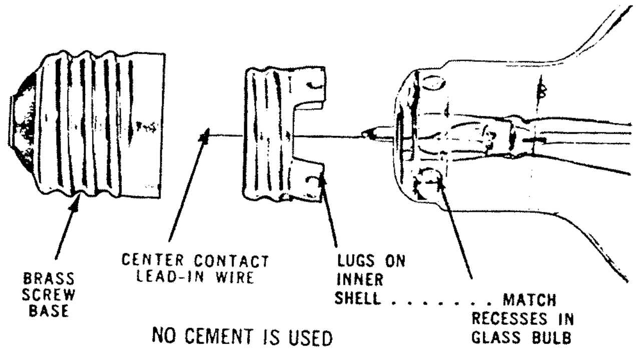


BASES WITH CABLES



7.4 BASE TO BULB ATTACHMENT

Most bases are cemented to the glass bulb. There are some exceptions such as the mogul mechanical base. Figure 7.4.1 shows and exploded view of the mechanical base.



Greater strength and better all-around performance are achieved from some of the higher wattage floodlight and street series lamps, as well as many general service lamps, by using a mechanical base. Similar in appearance to the regular mogul screw base, this base eliminates cements, and consists essentially of an inner shell, and a brass screw base. Recesses are molded into the glass at the bulb seal. Lugs on an inner metal shell snap snugly into these recesses when the two parts are assembled. The outer brass screw shell is then threaded on the inner shell, forcing the lugs securely into position. When secure, the outer shell is punch-locked to the inner shell in three places. Mechanical bases should not be operated at temperatures in excess of 400°F.

FIGURE 7.4.1

LAMP BASES

Another exception is the mogul bipost. The base for the bipost lamp is an integral part of the lamp attached by a glass-to-metal seal. Other lamps of this nature include automative wedge base lamps, baseless cartridge lamps, etc. Figure 7.4.2 shows the base pins of a mogul bipost lamp.

The rugged post-type contacts of the mogul bipost base lamp are extensions of the heavy filament support rods. Considerable heat is conducted from the filament to the external posts or contacts. Because of this, lamp-holders must be designed for temperatures in the order of 550°F.

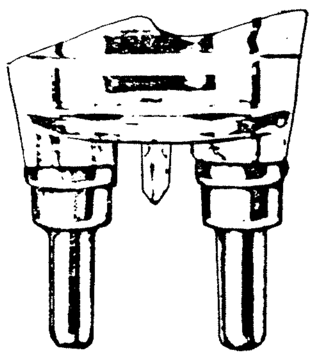


FIGURE 7.4.2

7.4.3 CEMENT SYSTEMS

There are several cements and cementing systems used to attach bases to bulbs. The systems fall into two categories - cold basing (cold cement curing) and hot basing (hot cement curing).

Cold Cement Curing is used only for specialized cases where heat from basing fires would be detrimental to the lamp. Micro-miniature lamps are often mounted with room temperature curing cement.

Hot Cement Curing

Green Cement

The normal basing cement commonly known as the green cement, is the most widely used and the least costly. It contains marble flour, phenolic resin, shellac and malachite green. The liquid used to moisten the cement is alcohol. The phenolic resin makes the base stick to the glass in the seal area. Rosin and shellac help the flow characteristics and also work as adhesives. The marble flour is a filler used in making the paste. The malachite green is a temperature indicating dye which changes from green to colorless to various shades of brown when heated. When the proper amount of heat is supplied most of the malachite green changes to colorless and the bulk of the cement looks brown in color with small sections of greenish cement present. The curing of the cement is a time-temperature operation and the adhesion depends on various things such as the freshness of the cement, the consistency of the mix, the amount of cement, and how the heat is applied. Obviously, if

7.4.3 GREEN CEMENT - (CONTD.)

more cement is added to cover more of the seal and base area, the base will hold on better. There is a limit to the amount of cement that can be added, however. With too much cement, some will fill the stem tube and also come out of the eyelet hole while the base is being heated. The cement in the stem tube can cause cracks in the seal and broken tips.

Purple Cement

The second type of cement is the purple silicone cement. This cement is used on long life lamps and lamps which burn a little hotter than the lamp using the green cement. It consists primarily of the green cement with approximately 3% to 5% of silicone resin added. The purple dye is used in place of but in the same way as the malachite green in the green cement.

Double Fill - Green and White Cement

The third type of cement fill is the two-part or double-fill. It consists of a band of green cement and a band of white cement. The white cement contains only marble flour and a large percentage of silicone resin. It is used when extremely high temperatures are encountered such as in the 1500W PS52 lamps. The green cement holds the lamp on the base initially but later on it deteriorates and is of little value. It is at that time that the white cement plays its role and holds the base on the lamp until the lamp fails. The white cement is not cured on the basing wheel but it cures during the time the lamp is burning.

7.4.3 DOUBLE FILL FOR BASE ARC PROTECTION

Another type of fill is the double-fill for a high voltage lamp. A ring of cement is placed near the bottom of the base and allowed to harden over a period of weeks. A second fill is then inserted and the base placed on the lamp after the normal waiting period for the regular green cement. The extra ring of cement is used to prevent the burning of a hole in the base when the fuse fails. It insulates the center lead wire from the shell of the base. When a fuse fails it produces many particles of material that could carry current thus providing an electrical path from the center wire to the shell if there were an opening there. This condition is prevalent in most lamps but is more critical in a lamp on higher voltage. In some decor lamps, a larger amount of basing cement is used to reduce the percentage of base arcs.

Advantages of hot cement:

1. Generally a better adhesion is achieved than in cold basing because during the setting process the cement flows into all the cavities between base shell and bulb.
2. The bases can be cemented beforehand without immediate application being necessary. Although the time between cap-filling and capping is limited for most of the cements used, it is amply sufficient to keep up with productions.
3. The possibility of preparing large quantities of resinous powder, from which the amounts needed are taken to make cements

7.4.3 ADVANTAGES OF HOT CEMENT - (CONTD.)

by adding the necessary solvent. This can be distributed to consumers all over the world in the dry form.

Drawback of this method:

Risk of accidental cracking off due to strain in the seal. This risk can be reduced to a minimum by accurate settings of the burners on the sealing and finishing machines.

Basing cement has strong adhesion under normal conditions, but over-heating of the base over a long period of time can cause the cement to lose its adhesive properties and the base may separate from the bulb.

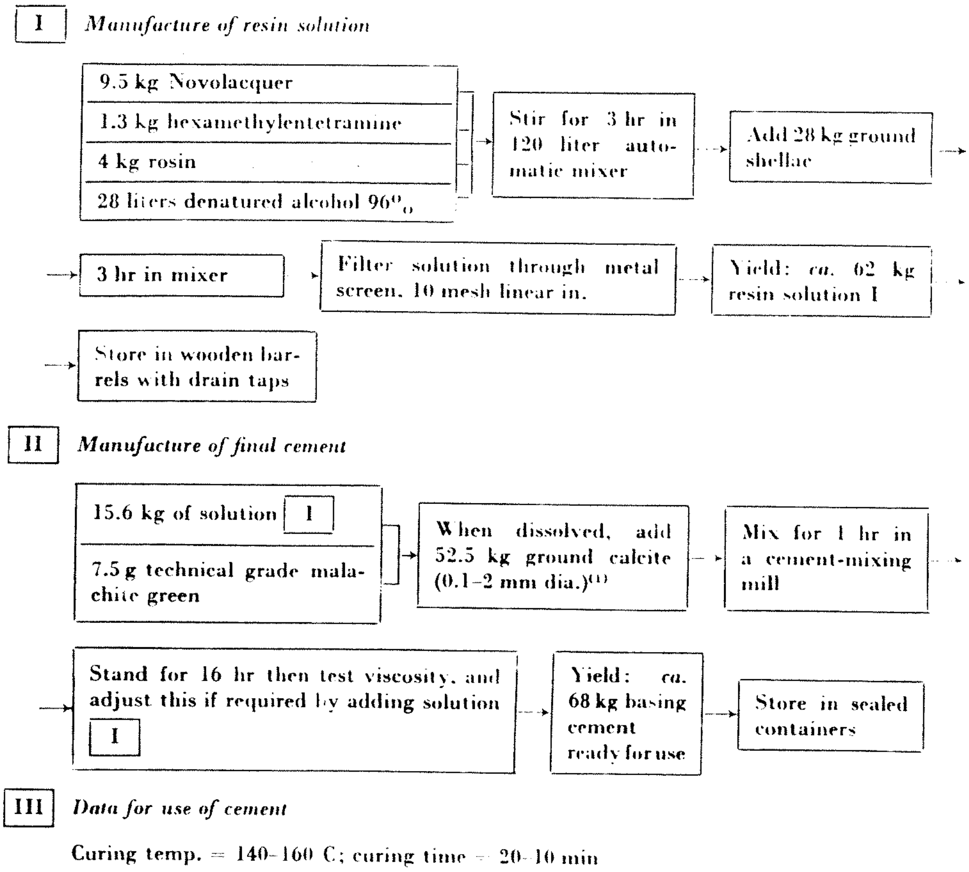
7.4.3.2 Maximum Safe Operating Temperature

The maximum safe temperature for basing cement used on standard general service lamps is about 340^{o}F, measured at the junction of the base and bulb. Special high-temperature silicone cement can withstand temperatures up to 500^{o}F. Above 300 watts, all general service lamps have mogul screw bases, many of which are mechanically secured to the bulb.

The first indication that a lamp is being over-heated, either because of a confining fixture or high ambient temperature, is when the bulb loosens from the base.

7.4.3.3 Typical Cement Recipe

A typical cement recipe is as follows:



7.4.3.3 TYPICAL CEMENT RECIPE - (CONTD.)

Changes in cement recipe are made for higher temperature operation (more silicone), whiter cement (add Lithophane or Titanium white) for some miniature lamps.

The fluidity of the cement is mainly controlled by the resin content. Heat resistance decreases as organic resin content increases. The addition of silicones (rubber and/or resin) will increase heat resistance.

Pot life and sufficient curing on finishing machine is a function of the resin and curing agents.

Good adhesion (bond) is chiefly a function of the resin. For example: shellac adheres well to glass and being thermoplastic, will aid in flowing of the cement during cure.

To prevent ring-off, some elasticity of cement is required. For proper elasticity, the fillers must not be too hard.

7.4.3.4 Fluidity and Viscosity

Before the cement is loading into the base filling equipment, the cement should be tested for proper fluidity and viscosity.

Problems resulting from viscosity changes include:

Low viscosity

(a) cement flows from base (manual threading -- base up)

(b) cement flows to bottom of base (automatic threading -- base down)

(c) risk of bursting of bulbs in soldering due to vapours evolved when using excess of solvent.

7.4.3.4 FLUIDITY AND VISCOSITY - (CONTD.)

High Viscosity

(a) Cement ring is dropped from base or warped due to slight cohesion;

(b) there is insufficient flow of cement during basing.

Trouble resulting from the use of a cement of a deviating fluidity comprises:

Low Fluidity

Insufficient stuffing of clearance between glass and base.

High Fluidity

Rims of cement flowing out between base and side of bulb. Such cement must later be scraped off with a knife, frequently resulting in accidental cracking off of bulbs from bases.

Cements must be delivered in clean tins or drums. The presence of any old cement will inevitably give trouble when filling caps due to choking of the cement-hopper nozzle.

Prepared cement must be used as promptly as possible, storage of cements being avoided at all costs. Generally speaking, the cement must never be more than one week old.

If a cement is not used at once, it must be covered with a thin layer of resinous solution or refrigerated which will prevent it from drying out at the surface.

7.4.3.5 FRESHNESS TEST

There is a "rule of thumb" which can be used to determine the freshness of the cement. If you can take some of the cement out of the base and ball it up in your fingers, the cement is probably soft enough to use. If it falls apart in your fingers it is obviously old.

7.4.3.6 Torque Test

Base tests are made daily to determine how the base stays on the lamp. The lamp is placed in a base tester by first screwing it into the holder. Rubber cups are then adjusted so they grip the maximum diameter of the lamp. A torque is placed on the bulb. When the bulb loosens from the base, a pointer will indicate the failure in inch-pounds - a good score is around 100. (See GTE Sylvania Specification H2E0404-711-712A and Specification #2E0300-6.)
A Boiling Water Test is also made. The lamps are placed in boiling water for a few minutes then partially dried. A torque test is made and the reading recorded. This test is made to simulate the shelf life of the base on the lamp during warehousing.

7.4.4 Base Filling

The nozzle on the base filling machine extrudes a ring of cement on to the base. The fillings applied to the bases must be correct and uniform.

1. The spread in the quantities applied must be within the limits specified.

7.4.4 BASE FILLING - (CONTD.)

2. The cement must be distributed uniformly in the base: There must not be much cement on one side and little on the other (skew ring).
3. The ring of cement must not be tall and thin but short and thick, though it must clear the lamp seal.
4. The ring should be placed as high in the base as possible because this will ensure proper stuffing of the clearance between base and bulb. Tests have shown that low (deep) application is far worse than a high position of the ring: The ring should start about 1-1.5 mm below the skirt (top) of the cap.

Cemented bases should be used promptly or stored in air-tight jars.

Shape of Lamp Seal

1. The diameter of the seal must not be too large. There must be enough clearance for threading without damaging the cement ring.
2. The seal must be tall enough to give a sufficient cement-to-glass contact area.
3. Relief in seal geometry will aid in achieving higher base torque tests.

7.4.5 BASING CEMENT CURING

Practically every cement contains a temperature indicator (malachite green). At a given setting time, the temperature range in which the indicator disintegrates and becomes colourless is about equal to the temperature required for the cement to set.

1. The cement must harden (set) in a fairly short time, the time during which the resin in the alcohol will have optimum flow due to heating.

This flowing of the cement is the most important phase of the basing process. During this phase the entire clearance between base and bulb must be filled properly.

Apart from the resin content, the time in which the solvent is evaporated is also important to achieve a proper flow.

If the time for setting is too short (very intense heating during a short time) the cement has not enough time to flow due to the solvent being evaporated too quickly.

If the time for setting is too long (slow heating up of cement), the alcohol will evaporate before the resin has melted and the cement will remain stationary, i.e. there will be no proper flow.

When cement is set, the temperature should be lowered gradually. If cooling is too rapid, accidental ring-off may occur.

Apart from failure to meet the above conditions because of incorrect temperature adjustments, there may be various troubles such as tarnishing of bases and oxidization of the leads, which hampers soldering at too high a cement temperature. If the

7.4.5 BASING CEMENT CURING - (CONTD.)

temperature of the cement (base) is too low, soldering will also be hampered due to the solder cooling too quickly as it gets on the base. (See 7.5.1)

The addition of trimethyl borate vapors to the gas-air burner mixture aids in prevention of tarnishing of brass bases and promotes solder wetting. The combustion gas is passed through a vessel containing the liquid trimethyl borate and then piped to mixers and burner as usual. The addition of the trimethyl borate causes the flame to turn various shades of green depending on the amount of trimethyl borate in the gas.

7.4.6 BASING CEMENT ADHESION TEST

To get an idea of the quality of the cement adhesion in finished lamps, torque tests under various conditions are made. (See 7.3.3.6)

The preliminary treatment may consist of:

(a) 24 hours' storage (so-called dry torque test).

(b) Between 1 and 4 weeks' stay in a 3-% common-salt solution in water, the lamp being suspended in the solution so as just to submerge the entire base.

(c) Between 1 and 4 weeks' stay in a tropical cabinet in which a relative humidity of 100% and a temperature of 40-50°C prevail.

(d) Life Testing.

(e) A proposed IEC specification for GLS lamps calls for placing the lamp in an oven at the maximum specified base service temperature for 1.5 X its rated life, followed by passage of a 3.0 newton-meter torque test.

7.4.6 BASING CEMENT ADHESION TEST - (CONTD.)

The requirements for the minimum torque-test values vary with lamp and base type. See GTE Sylvania Specification #2E0404-711-712A and Specification #2E0300-6.

7.5 Attaching Leads to Base

7.5.1 Soldering

Soldering is the process of joining two metals, e.g. brass, iron, copper, bronze-nickel alloys, etc., with the aid of a low-melting point metal. Soldering is done at approx. 300°C. This definition does not cover soldering of incandescent lamps, where the solder is not just an aid to join metals but an end: it serves as an electric contact. This does not really affect the principle of the procedure, it merely demands more stringent requirements for the joint.

(a) The joining must be quick.

(b) The joining must be reproducible and of a good quality.

(c) The joint must remain reliable under extreme thermal, climatic and mechanical load conditions, etc.

(d) The technique must cause no damage during or after the process (corrosion).

In soldering, frequent use is made of substances promoting the flow of the molten solder over the metal surface: the flux. Unless a flux is used, soldering is usually unsuccessful due to oxidation of the surface. Flux can be applied directly or contained in the core of the solder wire. An advantage of a good quality core solder

7.5.1 SOLDERING - (CONTD.)

is that the flux has been properly dosed. Core solders should be used as much as possible.

The action of a flux is mainly based on these functions:

(a) The cleaning of the basic metal surface from foreign matter including metal oxides.

(b) The cleaning of the molten solder surface and removal of oxides from the solder.

(c) The protection from foreign matter in the atmosphere attacking the two metals during soldering.

(d) The exertion of a favorable influence on surface tension (hypothetical). Addition of metal wetting agents, Lissapol NX.

The degree in which a flux performs these functions is the major consideration in selecting the right flux.

7.5.2 Corrosivity of Flux

The cleaning action of the flux is based on a combination of chemical and physical properties which result in attacking, dissolving or binding the contaminations. In most fluxes this aggressivity is still present after the soldering process, the remaining flux causing corrosion, which may have serious consequences. For this reason, acid flux is never used to solder the center contact since it could attack the lead inside the base after completion of center contact soldering.

7.5.3 TYPES OF FLUXES

(a) $ZnCl_2$ (zinc chloride) is a very corrosive acid flux and is not used for base soldering incandescent lamps.

(b) Rosin is a non-corroding flux. Its major constituent is abietic acid. Abietic acid is dissociated at soldering temperature and behaves as a weak acid. The basic difference between rosin and most other fluxes is:

1. Rosin is not dissociated at room temperature.
2. Rosin is almost insoluble in water.

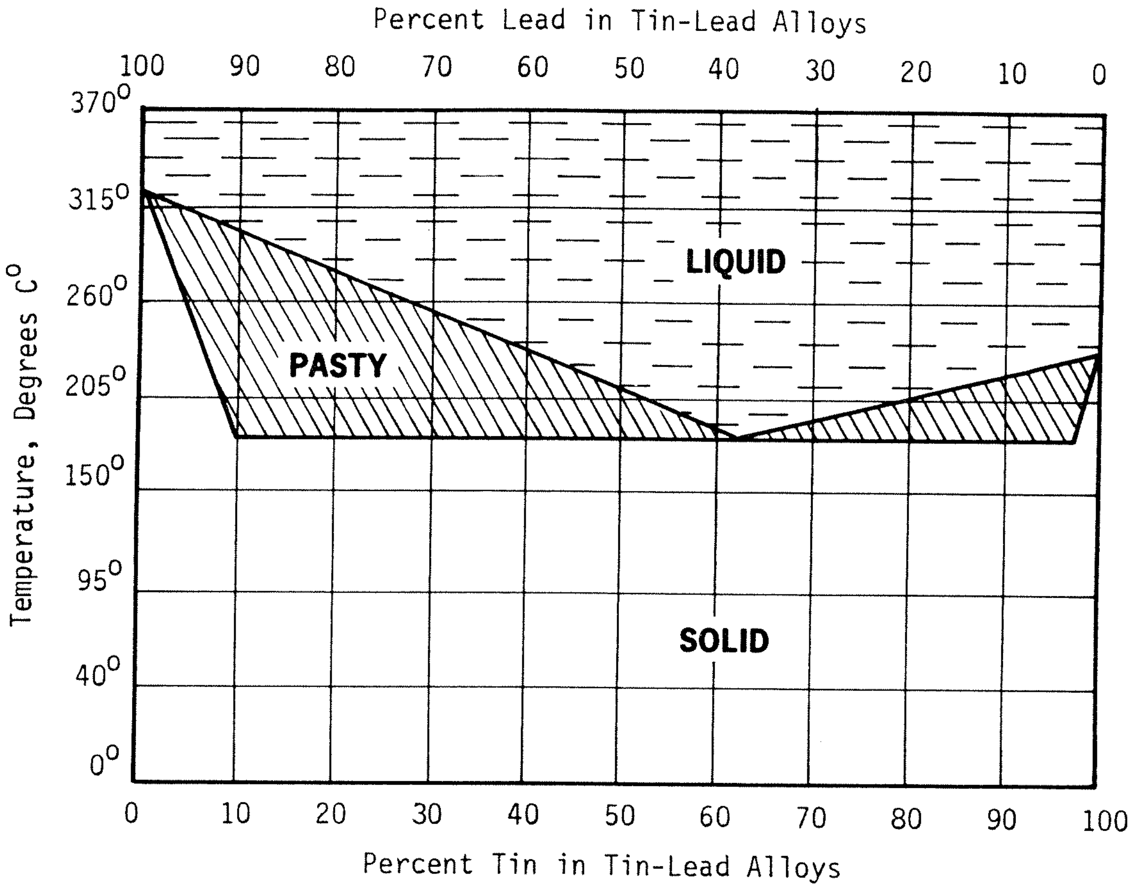
(c) A mixture of $ZnCl_2$, NH_4CL dissolved in water and emulsified with liquid petroleum into a paste has been used for incandescent lamps. Tin dust is sometimes added to the paste to get a pre-tinning effect.

7.5.4 Types of Solder

The type of solder is dependent upon the base material, the lamp wattage, and the end use to which the lamp is to be used. On "A" line lamps through 200W using aluminum bases, a low Cadmium solder - 30% Tin, 67% Lead has been used for the side wire connection. For high wattage lamps, a high Cadmium solder - 40% Cadmium, 60% Zinc - is used.

On brass bases, the Tin-Lead solders are common. The type specified is usually arrived at by compromise taking into account production equipment problems, cost, and lamp use. On high wattage lamps like the 1500W PS52, a very high temperature solder is used - 5% Silver and 95% Cadmium.

LAMP BASES



Automotive Lamps require a quick-flowing tin solder:

33 - 50 - 17 Cadmium Liquids 145°C

Lamps up to 200 W are soldered with 20-80 tin solder except some miniature lamps.

Lamps of 300 - 1000W require Cadmium solder.

7.5.4 TYPES OF SOLDER - (CONTD.)

Cadmium Solder - Melting Point 320°C.

Used for lamps whose operating temperature is at 300°C, e.g. Bakers' Oven Lamps.

Zinc chloride and water may be used as a flux for high-wattage (large) lamps, which require a Cadmium solder (m.p. 320°C), provided the cap is wiped properly after soldering. (There exists no Cadmium core solder).

Liquid flux, i.e. zinc chloride and water may also be used for low-wattage lamps that are hard to solder with a core solder, such as miniature lamps, automobile lamps, miners' lamps, etc.

7.5.4.1 Alloy Melting Temperatures

Alloy					
Tin		Lead	Solids	-	Liquids
20	-	80	180°	-	275°C
33	-	67	180°	-	250°C
40	-	60	180°	-	235°C
64	-	36	180°	-	182°C

ALUMINUM SOLDERING

40CD--60ZN (Higher Temp. Solder)	265°	-	335°
30SN-67PB-3CD	160°	-	240°
ALU-SOL Made by Multicore (Approximate temp.)	230°	-	280°

7.5.5 SIDE WIRE WELDING

To overcome the solder problems with aluminum bases, a method of welding the side wire to the base is used in Loring Ave., St. Mary's and Danvers, GTE Sylvania lamp plants.

There are many advantages to side wire welding - the elimination of solder and flux, the difficulty of bonding solder to aluminum, melting of the solder when the lamp is being used in high temperature locations and oversize solders preventing the lamp from properly seating in the socket.

"R F" (Radio frequency) is required to initiate the arc which subsequently melts the side wire and fuses it to the base shell.

THE FOLLOWING ARE FACTORS THAT AFFECT SIDE WIRE WELDING OPERATION: --

ALL SIDE WIRE POSITIONING AND CUTTING MECHANISMS HAVE A DIRECT RELATIONSHIP TO GOOD SIDE WIRE WELDING. PROPER POSITIONING, ALIGNMENT AND FORMING OF THE SIDE WIRE WILL CORRECT MOST WELDING DIFFICULTIES.

The height of the top caps can cause a variation in the height or length of the side wire.

The side wire cutter mechanisms should require very little adjustment, once installed properly. This should be checked by Mechanical Maintenance, however, for possible wear and proper adjustment or alignment during each routine machine maintenance check.

7.5.5.1 EQUIPMENT SETUP PROCEDURES

THE FOLLOWING STEPS SHOULD BE TAKEN DAILY TO INSURE AN EFFICIENT WELDING SETUP:

1. Wire Orientation - Observe side wire positioning mechanisms for proper function.

2. Wheel Assembly - New Ceramic Wheel properly gaged and positioned per specifications illustrated in manual. Wheel should be kept moist at all times when welding.

3. Electrodes - A new or redressed electrode properly gaged should be installed at the start of every shift.

4. Wheels and Electrode Assemblies - An extra unit of each should be properly gaged and ready for use in the event that they are needed. They may be quickly installed, therefore resulting in keeping defects to a minimum.

5. Ground Assembly - Ground Anvil must make contact with shell of base. Over-travel should not exceed one-eighth of an inch; too much over-travel will result in turning the lamp to the left, subsequently the side wire will also be off to the left and will not get welded properly.

6. After Welding Brush - Make sure it has been turned on and is free of dirt. While running off a few lamps for a dry run, observe the following:

   (a) Ceramic Wheel Functioning - Make absolutely sure that the wheel pushes the side wire up against the base lip so that a positive contact is made.

7.5.5.1 EQUIPMENT SETUP PROCEDURES - (CONTD.)

6. (b) When Finishing Head is not loaded with lamp, wheel overtravel should not exceed one-eighth of an inch.

   (c) Under no condition should the ceramic wheel make contact with the electrode.

7.5.5.2 Equipment Inspection

DURING PRODUCTION, THE FOLLOWING SHOULD BE INSPECTED HOURLY SO THAT EFFICIENT WELDING IS MAINTAINED:

1. Electrode Buildup - The electrode tip has a tendency to collect copper oxide buildup; an excess of buildup can result in the welding arc travelling directly to the base instead of side wire, causing a hole to be burnt into the base above the wire. To prevent this condition, it is recommended that the electrodes be brushed off during the hourly inspection.

2. Ceramic Wheel

   (a) Wet Ceramic Wheel - Wheel must be kept wet during welding; a steady dripping of water must be made available through the metering valve.

   (b) Wheel Defects - Observe Ceramic Wheel for any large chips or nicks - change if necessary.

   (c) Wheel Rotation - The Ceramic Wheel must rotate intermittently with the machine index. This will allow a moistened area of wheel to be present at the welding area at all times.

7.5.5.2 EQUIPMENT INSPECTION - (CONTD.)

2. (d) Ceramic Wheel Change - Wheels should be inspected at the beginning of every shift and changed if necessary.

3. Electrode Change - Electrodes must be changed every 4 or 5 hours or during the lunch break. This is because after 4 or 5 hours of continuous welding, the electrode will erode, causing the distance between the electrode and wire to increase beyond the range of efficient welding of the side wire. This results in missed or cold welds. A spare electrode should be set to gage at all times for quick change if necessary.

7.6 Reference for Additional In-Depth Information

1. Material Technology for Electron Tubes by W. H. Kohl, Reinhold Publishing Corp., 330 West 42nd St. New York, N.Y.

2. Welding and Other Joining Processes by R. A. Lindberg and N. R. Braton, Allyn and Bacon, Inc., Boston, Mass.

3. Lead Wires and Soldering by Robert H. Dickinson, GTE Sylvania, Loring Avenue, Salem, Mass. 01970.

4. Basing Cement Considerations by A. Tartakoff GTE Sylvania, Loring Avenue, Salem, Mass. 01970.

GLASS

8.0 Glass is a non-crystalline material that is rigid at ordinary temperatures and soft or almost fluid at elevated temperatures with no definite melting point in between. In this respect it is not unlike taffy or sealing wax.

Lamp glass is in two categories; hard glass and soft glass. These terms have no relationship to the mechanical hardness of glass. "Soft glass" refers to lime or lead glasses which have a high thermal expansion coefficient and low melting and forming temperature compared to "hard glasses" which are usually borosilicate glasses and have a lower thermal expansion coefficient and higher melting point.

8.1 Properties

Strain Point is the highest temperature from which glass can be cooled haphazardly without becoming permanently strained. Conversely, it is the lowest temperature at which permanent internal strains can be released. The strain point is sometimes considered to be the absolute upper limit of useful temperature range for annealed glasses. This, of course, assumes that in this elevated temperature region the glass will be protected from thermal shocks. Viscosity at the strain point is $10^{14.6}$ poises.

Annealing Point is the temperature where internal strains can be quickly relieved. Glass is annealed at temperatures in the vicinity of the annealing point. Viscosity at the annealing point is $10^{13.4}$ poises.

8.1 PROPERTIES (CONTD.)

Softening Point is the temperature where the glass begins to noticeably deform under its own weight. Viscosity at the softening point is $10^{7.6}$ poises.

Working Point is the temperature where the glass is soft enough for hot working by most of the common methods. Viscosity at the working point is 10^4 poises.

Glass is a strong material. Measurements on fine glass fibers give breaking strengths of one million psi or more. Table 8.1.1 shows the strength of glass formed by various processes.

HOW STRONG IS GLASS	
Micron fiber	1,000,000 to 100,000 psi
Commercial fibers	400,000 to 30,000
Drawn window glass	20,000 to 8,000
Blown ware	10,000 to 5,000
Pressed ware	8,000 to 3,000
Abraded surfaces	6,000 to 2,000
Deep file mark	1,500 to 500
Typical commercial part	5,000
Conservative design value	1,000

Table 8.1.1

For all ordinary purposes, it can be assumed that glass is perfectly elastic up to the point of fracture.

The following Table 8.1.2 shows the physical properties of common lamp glasses.

8.2 Glass Annealing

Glass is formed into bulbs, flares, stems, bridges, etc. During forming either part or all of the glass is heated to the working point. Cooling the finished part from the working point down through the strain point must be done in a controlled manner to avoid permanent strain which may cause cracks in time alone or due to slight additional strains which occur in normal temperature changes, shock, vibration, etc.

The final stress in a glass article of simple shape depends upon two factors. These factors are temperature and time of soaking, during which the stresses already present are reduced to a certain level; and the rate of cooling between the soaking temperature and a temperature which is, in most cases, the strain point.

The equation for determining this rate of cooling is:

$$R = \frac{5.7 \times 10^{-4} F}{x t^2}$$

Where R is the rate of cooling in $^{\circ}C$ per minute,

F is desired final stress (maximum tension) in Kg/mm^2

X is the expansion co-efficient applying to the annealing range in per $^{\circ}C$ and

t is thickness of glass in cm.

It should be noted that whenever the glass is allowed to cool in one direction only, the rate should be halved.

TABLE 8.1.2

METRIC

1	2	3	4	5	6				7		8				9		
					Corrosion Resistance				Thermal Expansion —Multiply By 10^{-7}cm/cm/°C		UPPER WORKING TEMPERATURES (Mechanical Considerations Only)				Thermal Shock Resistance Plates 15 x 15 cm		
											Annealed		Tempered		Annealed		
Glass Code	Type	Color	Principal Use	Forms Usually Available	Class	Weathering	Water	Acid	0-300°C	25°C to Setting Point	Normal Service °C	Extreme Service °C	Normal Service °C	Extreme Service °C	3.2 mm Thick °C	6.4 mm Thick °C	12.7 mm Thick °C
0010	Potash Soda Lead	Clear	Lamp Tubing	T	I	2	2	2	93.5	101	110	380	—	—	65	50	35
0080	Soda Lime	Clear	Lamp Bulbs	BMT	I	3	2	2	93.5	105	110	460	220	250	65	50	35
0120	Potash Soda Lead	Clear	Lamp Tubing	TM	I	2	2	2	89.5	97	110	380	—	—	65	50	35
0330	Glass-Ceramic	Gray	Bench Tops	RS	I	–	1	3	9.7	—	538	—	—	—	—	—	—
1720[4]	Aluminosilicate	Clear	Ignition Tube	BT	I	1	1	3	42	52	200	650	400	450	135	115	75
1723	Aluminosilicate	Clear	Electron Tube	BT	I	1	1	3	46	54	200	650	400	450	125	100	70
1990	Potash Soda Lead	Clear	Iron Sealing	—	II	3	3	4	124	136	100	310	—	—	45	35	25
2405	Borosilicate	Red	General	BPU	I	–	–	–	43	53	200	480	—	—	135	115	75
2473	Soda Zinc	Red	Lamp Bulbs	B	I	2	2	2	91	—	110	460	—	—	65	50	35
3320	Borosilicate	Canary	Tungsten Sealing	—	I	[3]1	[3]1	[3]2	40	43	200	480	—	—	145	110	80
6720	Soda Zinc	Opal	General	P	I	[2]–	1	2	78.5	90	110	480	220	275	70	60	40
6750	Soda Barium	Opal	Lighting Ware	BPR	I	[2]–	2	2	88	—	110	420	220	220	65	50	35
7040	Borosilicate	Clear	Kovar Sealing	BT	II	[3]3	[3]3	[3]4	47.5	54	200	430	—	—	—	—	—
7050	Borosilicate	Clear	Series Sealing	T	II	[3]3	[3]3	[3]4	46	51	200	440	235	235	125	100	70
7052	Borosilicate	Clear	Kovar Sealing	BMPT	II	[3]2	[3]2	[3]4	46	53	200	420	210	210	125	100	70
7056	Borosilicate	Clear	Kovar Sealing	BTP	II	2	2	4	51.5	56	200	460	—	—	—	—	—
7070	Borosilicate	Clear	Low Loss Electrical	BMPT	I	[3]2	[3]2	[3]2	32	39	230	430	230	230	180	150	100
7251	Borosilicate	Clear	Sealed Beam Lamps	P	I	[3]1	[3]2	[3]2	36.7	38.1	230	460	260	260	160	130	90
7570	High Lead	Clear	Solder Sealing	—	II	1	1	4	84	92	100	300	—	—	—	—	—
7720	Borosilicate	Clear	Tungsten Sealing	BPT	I	[3]2	[3]2	[3]2	36	43	230	460	260	260	160	130	90
7740	Borosilicate	Clear	General	BPSTU	I	[3]1	[3]1	[3]1	32.5	35	230	490	260	290	160	130	90
7760[5]	Borosilicate	Clear	General	BP	I	2	2	2	34	37	230	450	250	250	160	130	90
7800	Soda Barium Borosilicate	Clear	Pharmaceutical	T		1	1	1	50	53	200	460	—	—	—	—	—
7900[1]	96% Silica	Clear	High Temp.	BPTUM	I	1	1	1	8	5*	800	1100	—	—	—	—	—
7913[1]	96% Silica	Clear	High Temp.	BPRST	I	1	1	1	7.5	5.5*	900	1200	—	—	—	—	—
7940	Fused Silica	Clear	Optical	U	I	1	1	1	5.5	3.5*	900	1100	—	—	—	—	—
7971	Titanium Silicate	Clear	Optical	U	–	1	1	1	0.5	–2	800	1100	—	—	—	—	—
8160	Potash Soda Lead	Clear	Electron Tubes	PT	II	2	2	3	91	100	100	380	—	—	65	50	35
8161	Potash Lead	Clear	Electron Tubes	PT	I	2	1	4	90	99	100	390	—	—	—	—	—
9606	Glass-Ceramic	White	Missile Nose Cones	C	II	–	1	4	57	—	700	—	—	—	200	170	130
9608	Glass-Ceramic	White	Cooking Ware	BP	I	–	1	2	4-20	—	700	800	—	—	—	—	—
9741	Borosilicate	Clear	u v Transmission	BUT	II	[3]3	[3]3	[3]4	39.5	50	200	390	—	—	150	120	80

COLUMN 1

[1]Glasses 7905, 7910, 7911, 7912, 7913 and 7917 for special ultraviolet and infrared applications.

[4]Glass 1720 is available with improved ultraviolet transmittance (designated glass 9730).

[5]Glass 7760 also available with special transmission suitable for sun lamps.

COLUMN 5

B—Blown Ware P—Pressed Ware S—Plate Glass
M—Multiform R—Rolled Sheet T—Tubing and Rod
U—Panels C—Castings

COLUMN 6

[2]Since weathering is determined primarily by clouding which changes transmission, a rating for the opal glasses is omitted.

[3]These borosilicate glasses may rate differently if subjected to excessive heat treatment.

COLUMN 7

*Extrapolated values.

Code 9608 may be produced in a range of expansion values depending upon intended application.

COLUMN 8

Normal Service: No breakage from excessive thermal shock is assumed.

Extreme Limits: Glass will be very vulnerable to thermal shock. Recommendations in this range are based on

All data subject to normal manufacturing variations

TABLE 8.1.2

10	11				12	13	14		15			16			17	18
Thermal Stress Resistance °C	Viscosity Data				Knoop Hardness KHN_{100}	Density g/cm³	Young's Modulus Multiply By 10³ Kg/mm²	Poisson's Ratio	Log_{10} of Volume Resistivity ohm-cm			Dielectric Properties at 1 MHz, 20°C			Refractive Index	Glass Code
	Strain Point °C	Annealing Point °C	Softening Point °C	Working Point °C					25°C	250°C	350°C	Power Factor %	Dielectric Constant	Loss Factor %		
19	392	432	626	983	363	2.86	6.3	.21	17.+	8.9	7.0	.16	6.7	1.	1.539	0010
16	473	514	696	1005	465	2.47	7.1	.22	12.4	6.4	5.1	.9	7.2	6.5	1.512	0030
20	395	435	630	985	382	3.05	6.0	.22	17.+	10.1	8.0	.12	6.7	.8	1.560	0120
178	—	—	—	—	522	2.54	8.8	.26	—	—	—	—	—	—	—	0330
28	667	712	915	1202	513	2.52	8.9	.24	17.+	11.4	9.5	.38	7.2	2.7	1.530	1720
26	665	710	908	1168	514	2.64	8.8	.24	17.+	13.5	11.3	.16	6.3	1.0	1.547	1723
14	340	370	500	756	—	3.50	5.9	.25	17.+	10.1	7.7	.04	8.3	.33	—	1990
37	501	537	765	1083	—	2.48	6.9	.21	—	—	—	—	—	—	1.507	2405
19	466	509	697	—	—	2.65	6.7	.22	—	—	—	—	—	—	1.52	2473
43	493	540	780	1171	—	2.27	6.6	.19	—	8.6	7.1	.30	4.9	1.5	1.481	3320
20	505	540	780	1023	—	2.58	7.1	.21	—	—	—	—	—	—	1.507	6720
18	447	485	676	1040	—	2.59	—	—	—	—	—	—	—	—	1.513	6750
37	449	490	702	1080	—	2.24	6.0	.23	—	9.6	7.8	.20	4.8	1.0	1.480	7040
39	461	501	703	1027	—	2.24	6.1	.22	16.	8.8	7.2	.33	4.9	1.6	1.479	7050
41	436	480	712	1128	375	2.27	5.8	.22	17.	9.2	7.4	.26	4.9	1.3	1.484	7052
33	472	512	718	1058	—	2.29	6.5	.21	—	10.2	8.3	.27	5.7	1.5	1.487	7056
66	456	496	—	1068	—	2.13	5.2	.22	17.+	11.2	9.1	.06	4.1	.25	1.469	7070
48	500	544	780	1167	—	2.25	6.5	.19	18.	8.1	6.6	.45	4.85	2.18	1.476	7251
21	342	363	440	558	—	5.42	5.6	.28	17.+	10.6	8.7	.22	15.	3.3	1.86	7570
49	484	523	755	1146	—	2.35	6.4	.20	16.	8.8	7.2	.27	4.7	1.3	1.487	7720
54	510	560	821	1252	418	2.23	6.4	.20	15.	8.1	6.6	.50	4.6	2.6	1.474	7740
52	478	523	780	1198	442	2.24	6.3	.20	17.	9.4	7.7	.18	4.5	.79	1.473	7760
33	533	576	795	1189	—	2.36	—	—	—	7.0	5.7				1.491	7800
207	820	910	1500	—	463	2.18	6.9	.19	17.	9.7	8.1	.05	3.8	.19	1.458	7900
220	890	1020	1530	—	487	2.18	6.9	.19	17.+	9.7	8.1	.04	3.8	.15	1.458	7913
286	956	1084	1580	—	489	2.20	7.4	.16	17.+	11.8	10.2	.001	3.8	.0038	1.459	7940
3370	—	1000	1500	—	—	2.21	6.9	.17	20.3	12.2	10.1	[6]<.002	[6]4.0	[6]<.008	1.484	7971
18	397	438	632	973	—	2.98	—	—	17.+	10.6	8.4	.09	7.0	.63	1.553	8160
22	400	435	600	862	—	3.99	5.5	.24	17.+	12.0	9.9	.06	8.3	.50	1.659	8161
16	—	—	—	—	657	2.6	12	.24	16.7	10.0	8.7	.30	5.6	1.7	—	9606
—	—	—	—	—	593	2.5	8.8	.25	13.4	8.1	6.8	.34	6.9	2.3	—	9608
54	408	450	705	1161	—	2.16	5.0	.23	17.+	9.4	7.6	.32	4.7	1.5	1.468	9741

mechanical stability considerations only. Tests should be made before adopting final designs.
These data approximate only.

COLUMN 9

These data approximate only.
Based on plunging sample into cold water after oven heating. Resistance of 100°C (212°F) means no breakage if heated to 110°C (230°F) and plunged into water at 10°C (50°F). Tempered samples have over twice the resistance of annealed glass.

COLUMN 10

Resistance in °C (°F) is the temperature differential between the two surfaces of a tube or a constrained plate that will cause a tensile stress of 0.7 kg/mm² (1000 psi) on the cooler surface.

COLUMN 11

These data subject to normal manufacturing variations.

COLUMN 12

Determined by revised ASTM standard: number of standard not yet assigned.

COLUMN 15

[6]at 10 kHz

COLUMN 17

Refractive Index may be at either the sodium yellow line (589.3 nm) or the helium yellow line (587.6 nm). Values at these wavelengths do not vary in the first three places beyond the decimal point.

Putting in the proper constant for low expansion glasses:

$$E = 32 \times 10^{-7} \quad \text{(approximately)}$$

and assuming a safe final stress of:

$$F = 0.2 \text{ Kg/mm}^2$$

$$R = \frac{4 \times 10^{-4} \times 0.2}{32 \times 10^{-7}\, t^2} = \frac{25}{t^2}$$

For various glass thickness, this expression gives the following rates:

Thickness	Cooling Rate
8 mm.	39°C/min.
6	69
4	156
3	278
2	625
1	2500

For high expansion glasses: $E = 90 \times 10^{-7}$ (approximately).

A similar table becomes:

Thickness	Cooling Rate
8 mm.	14°C/min.
6	25
4	56
3 mm.	99
2	222
1	890

After cooling has proceeded to some 20°C below the strain point, the rate may be increased since no further change of final stress is possible. The final speed is only limited by the ability of the glass to withstand temporary stresses. A safe value for temporary maximum tension may be taken as:

$$F = 0.75\ Kg/mm^2$$

Possible maximum cooling rates after annealing will then be:

Thickness	Low Expansion	High Expansion
8 mm.	146°C/min.	52°C/min.
6	259	94
4	585	210
3	1040	371
2	2340	830
1	9400	3340

The above analysis is predicated upon uniform conditions of temperature throughout the articles. The kind of annealing used most frequently in lamp factories, in which fires are played upon the article, cannot produce the stipulated condition of uniformity.

With flame annealing, therefore, there is always a spottiness of temperature which completely nullifies any computed annealing schedules and the matter becomes entirely empirical. The net result is that even though the cooling rate is low, mechanical stresses develop as soon as uniformity is re-established at room temperature.

Accordingly, the only way that proper annealing can be accomplished is to establish as nearly as possible temperature uniformity over the whole article during the passage through the annealing range. It is not necessary to do this completely, as would be the case in muffle annealing, but the nearer the approach is to such conditions the nearer also will be the approach to a computed value of final stress.

8.3 Stresses in Incandescent Lamp Glass

The properties of glass under stress are quite different from those of metals. When subjected to stress, glass fails suddenly without yield or deformation, while metals will show plastic deformation.

This is illustrated in Fig. 1 and for glass, it is seen that the strain increases at the same rate as the stress increases up to the point of actual fracture. In metals, a point is reached, before fracture occurs, where only a small increase in the applied stress results in a much larger change in strain in the sample; that is, the metal deforms on application of further stress.

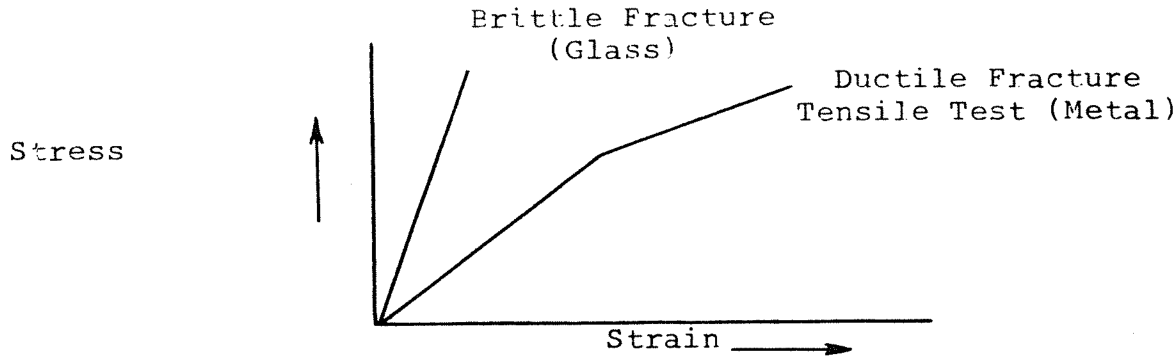


Fig. 1 Brittle and Ductile Fracture

It is for this reason that glass is considered an elastic material. The inherent strength of glass is very high (6 to 13 million lbs./square inch) and when subjected to stress for short periods, the resultant strain will disappear after removal of the stress and the original dimensions return.

It is generally accepted that glass will break only when in tension. A tensile strength of 1000 lbs. per square inch (psi) is normally accepted for the tensile strength of glass.

Heating of the glass for flare, stem, or sealex operations creates temporary stresses in the glass. Glass is a poor conductor of heat and a high stress build-up will lead to fracture if caution is not taken in raising the temperature of the glass slowly and uniformly.

To picture what happens during heating of the glass, assume that the wall of the glass is composed of two separate sections; an outer surface (1) and an inner surface (2), as in Fig. 2 (a).

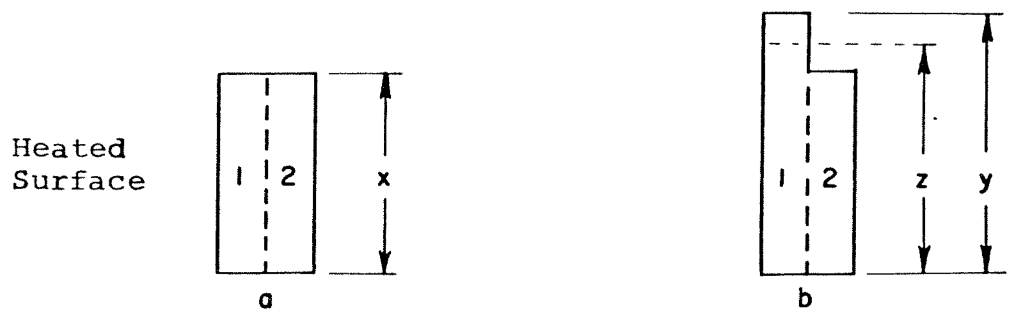


Fig. 2 Development of Temporary Stresses in Glass during Heating Below the Strain Point

At room temperature, both outer and inner surface are at the same temperature and, therefore, have the same length, (x).

GLASS

On application of heat to the outer surface (1), it will try to expand to a length (y), while the inner surface remains the same (x), as in Fig. 2 (b). Realistically, the two sections are not free to move independently and a compromise length (z) will result in the actual amount of total expansion of the glass. The net effect is that the outer surface cannot expand to the extent that it would if it were free (length y) and it is seen that the compromise length (z) is shorter than the "free" length (y). It indicates that the heated outer surface is shortened or in compression while being heated and the inner surface is forced to stretch from its original length (x) to the compromise length (z), thereby replacing it in tension.

It is for this reason that glass tubing cutters scribe the glass on the outside and then apply heat on the inside of tubing (Swanson-Erie for example).

If the rate of heating has been controlled to avoid fracture, the glass rises in temperature and when the strain point is reached, temporary stresses due to the temperature difference between the two sections will be relieved by viscous flow, that is, as it softens slightly. Heating can then be increased rapidly to the point necessary to perform the operations intended; that is, flare, stem or lamp-making without stresses developing.

GLASS

The viscosity of the glass changes gradually with temperature (Fig. 3). Four points on this curve are important in understanding the relationship of temperature on the softness of the glass in its change from a solid to a liquid and in the strain produced in the glass.

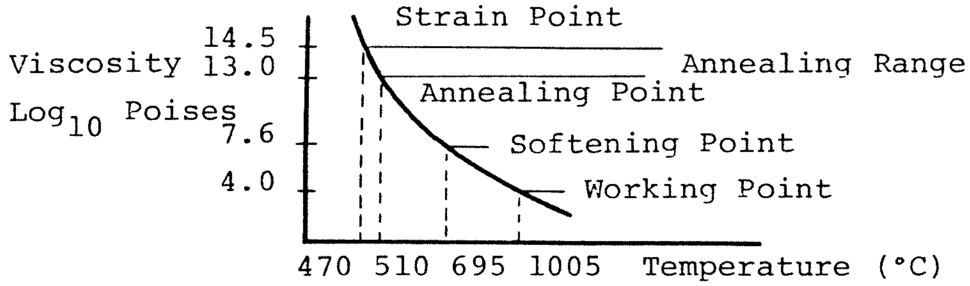


Fig. 3 Viscosity-Temperature Relationship of 0080 Glass

The strain point represents temperature at which most of the stress developed internally is relieved if held there for 4 hours. Thus for 0080 glass (soft glass) used in most incandescent bulbs, a temperature of 470°C is indicated. This point is also the lower limit of the annealing range and glass may be heated up to this point without causing permanent stresses.

The annealing point represents the temperature at which most of the stress developed internally is relieved if held there for 15 minutes. Again, for 0800 glass, a temperature of 510°C is indicated. It is also the upper limit of the annealing range and above this point, distortion of the glass will result.

Annealing is accomplished by holding the glass between 470°C and 510°C (for 0800 glass) and slowly cooling within this range to below the strain point to prevent permanent stresses from developing.

The softening point represents the temperature at which glass rapidly deforms and starts to adhere to other materials. Fig. 3 shows this to be 695°C for soft glass (0080 glass).

The working point is the temperature where the glass is soft enough to allow bell-reaming for flares, stem-pressing at Automount, or sealing-in at Sealex. It is 1005°C for soft glass (0080 glass).

After these operations are completed, the problem of introducing permanent or temporary stresses in the glass by cooling too rapidly must be considered.

The ideal temperature cycle that the glass goes through on a Sealex unit is shown in Figure 4. The distribution of stresses that can result on cooling is explained below.

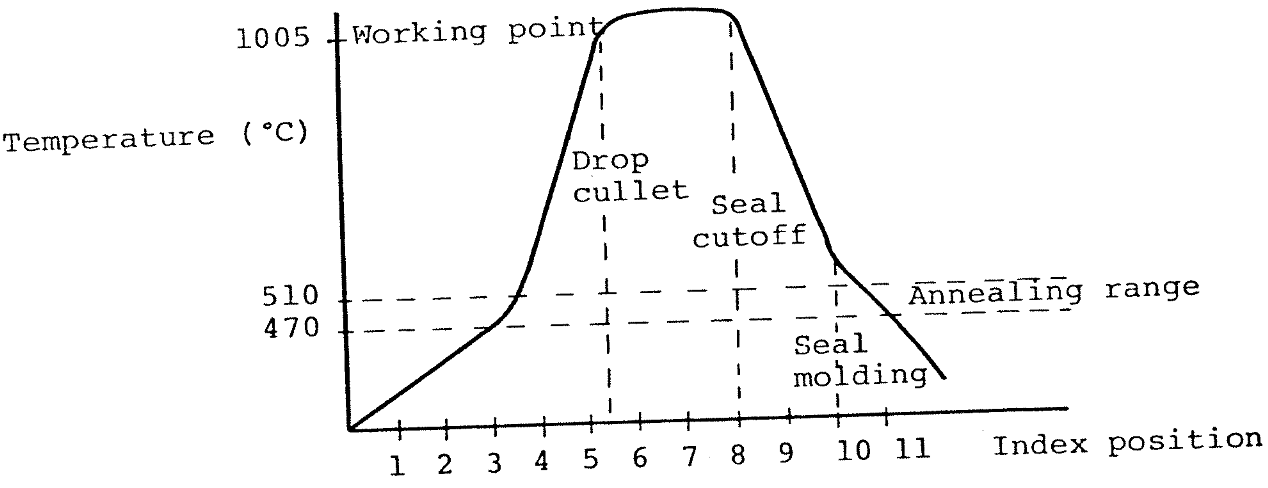


Fig. 4 Temperature Cycle of Glass on G.E. Sealex Unit

GLASS

After the glass has been worked to produce the final shape and dimensions desired; for example, molding of the seal at Sealex, it is at a temperature (550°C), only slightly above the annealing point.

Permanent stresses can be introduced in the glass only when it is in the semi-rigid state referred to as the annealing range. On cooling the outer surface (1), as in Fig. 5 (a), while in this range, it will contract more rapidly than the inner surface (2). If they were independent of each other, the outer surface will contract to a length (y), as in Fig. 5 (b), while the inner surface remains at the original length (x).

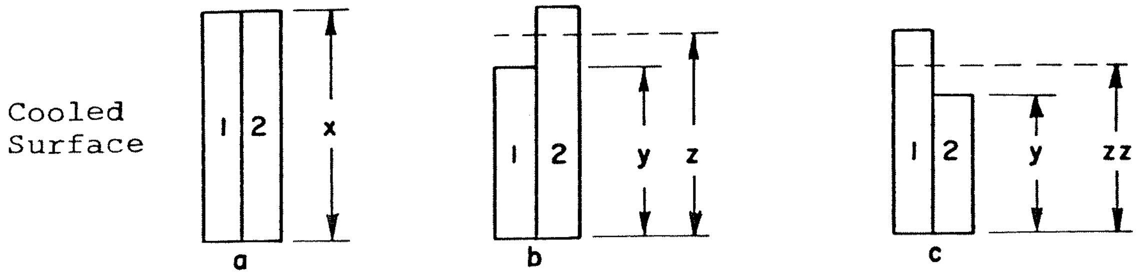


Fig. 5 Development of Permanent Stresses During Cooling in the Annealing Range

If cooling of the glass is too rapid to allow the inner surface enough time to contract to a length equal to that of the outer surface, then the compromised length (z) results temporarily. This compromise length (z) is longer than the desired length (x) of the outer surface, indicating that the outer surface is stretched or in tension. At the same time, the inner surface (2), which is not cooling as fast, must shrink or compress to reach this compromise length, therefore, it is in compression.

Since the outer surface is the one being cooled, it goes through the strain point first, becomes rigid, at the compromised length (z), as in Fig. 5 (c).

The inner surface, also at the compromise length (z) is still semi-rigid and able to flow to a small extent. So it continues to contract, and compresses the rigid outer surface to a new compromise length (zz). In doing so, the inner surface becomes stretched, or is in tension, until it also becomes rigid when it is cooled to below the strain point. Now the stress is such that the outer surface is in compression and the inner surface, in tension. This pattern will be the final pattern when it is finally cooled to room temperature. If the cooling rate of the glass was slow enough to allow both inner and outer surface to contract at an equal rate, no permanent stress would be found when it reached room temperature. Picture that the glass temperature is uniform through the whole body, at a temperature just below the strain point, both surfaces having a length (x), as in Fig. 6 (a).

Fig. 6 Development of Temporary Stresses in Glass During Cooling Below the Strain Point.

The outer surface (1) will contract to a length (y) if cooled too rapidly; for example, by cooling air hitting the glass or by contact to metal. The inner surface will remain at the original length (x), since it has not been cooled yet. The outer surface, in a practical sense, is not free to contract independently and a compromise between the desired length (y) and the original length (x) will result; designated again by length (z) Fig. (6b). It is seen that the outer surface (1) is shorter than the compromise length, so it is stretched to this length, thereby placing it in tension. Also, the inner surface, which was at a larger length than the compromise length must be compacted to arrive at this length, thereby placing it in compression.

The influence of heating and cooling glass on the stresses developed is summarized in Table I.

Table I. Effect of Temperature Distribution in Glass on Stress Development

	Hot Surface	Cold Surface
Heating (below strain point)	Compression (Temporary)	Tension (Temporary)
Cooling (in annealing range)	Compression	Tension
Cooling (below strain point)	Tension (Temporary)	Compression (Temporary)

Other factors besides temperature are important in forming a lamp that will not crack. It was stated before that the safe limit used as a guide for glass tensile strength is 1000 psi. If sharp angles are present in the stem press Fig. 7 (a) or in the seal area, they will create areas that are very sensitive if stresses are applied.

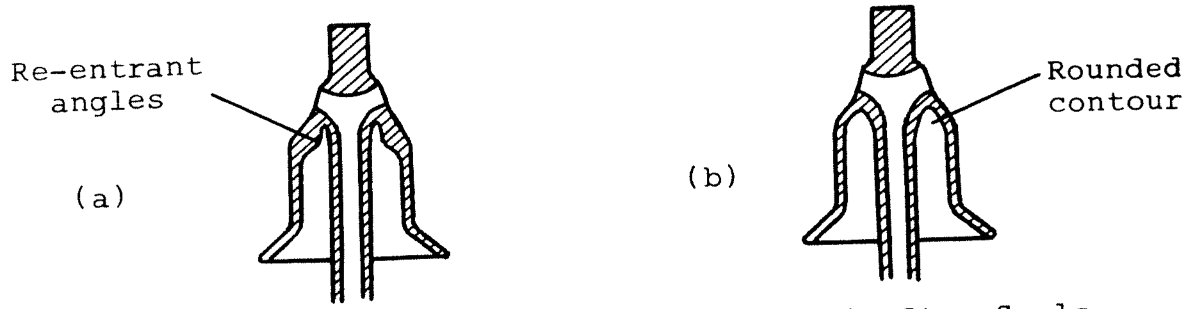


Fig. 7 Contours of Good and Poor Geometry in Stem Seals.

For instance, a stem with sharp re-entrant angles between the flare and exhaust tube will not be able to survive the mechanical shock at the Sealex operation. It will either break in the mold position, at lamp transfer to exhaust, or in the exhaust tube tipping position. A shape as in Fig. 7 (b) is desirable to give the stem the necessary safety margin to withstand these mechanical shocks.

8.3.1 Rules of Good Glass Practice

In general, the major points to remember about good glass practice in incandescent lamp-making can be listed as follows:

1. Glass is an insulator so heat cannot move quickly and uniformly through it.
2. Glass breaks only when in tension.
3. Heating and cooling must be carried out as slowly as possible; in the annealing range to reduce the permanent stresses that will cause delayed cracks to occur, and below the strain point, to minimize the temporary stresses from exceeding its tensile strength

8.3.1 RULES OF GOOD GLASS PRACTICE (CONTD.)

3. limit, causing immediate cracks to occur; during pre-heating or final cooling.

4. Sharp angles in its shape will reduce its strength considerably.

8.4 Fracture Analysis of Glass

During normal incandescent lamp manufacture, glass breakage occurs due to various reasons. In order to minimize glass loss at the separate operations involved, fracture analysis performed on the glass shrinkage is vital to obtain accurate and rapid correction of the fracture cause. This analysis provides knowledge of the fracture origin, direction and amount of stress involved at the time of failure.

The main concern is with the conditions leading to fracture of the glass surface, since it is the tensile stress at a tiny flaw on the surface that leads to fracture, rather than the tensile stress in the main body of the glass.

A typical glass fracture (Fig. 1) will show a shiny "mirror" surface surrounding the actual fracture origin with a frosted appearance at the outer edge of this mirror.

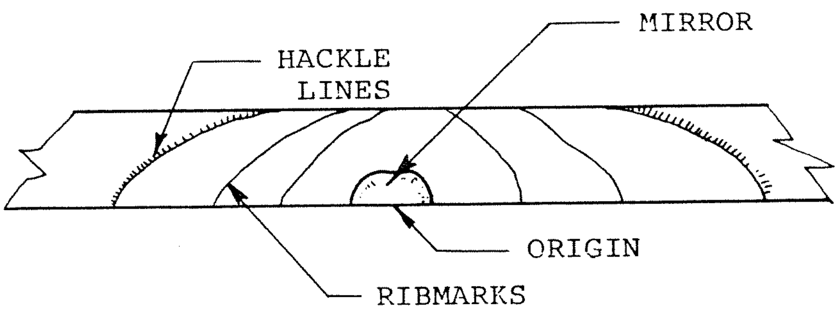


Fig. 1 Typical Glass Fracture Pattern

GTE Sylvania Company Private

8.4 FRACTURE ANALYSIS OF GLASS (CONTD.)

Radiating outward from the "mirror" are rib-marks which indicate the direction of fracture travel and magnitude of stress involved at the time of fracture. Perpendicular to the rib-marks may be seen "hackle lines". These are small, closely-spaced lines related to the actual fracture process and they occur only when an applied stress is present, never in annealed glass.

8.4.1 General Guidelines

Interpretation of a fracture pattern requires a knowledge of the processes involved in incandescent lamp-making, as well as general guidelines of glass fracture analysis. These guidelines are listed as follows:

1. The fracture surface of the glass reveals only the tensile stress that is perpendicular to the fracture surface. The tensile stress which produced the crack will be in a direction normal to the plane of the mirror area.

2. Origin: The point of actual failure due to a tensile stress acting on the glass surface. The origin will be located at the center of a smooth plane called the mirror area. This point can often be related to a specific flaw such as a scratch, bruise check, fire crack, foreign inclusion in the surface, or in some cases a reentrant angle which acts as a stress concentrator.

3. Mirror: The shiny area surrounding the fracture origin. Generally, the mirror is small when fracture is due to a high stress, and it is large, when due to a low stress.

8.4.1 GENERAL GUIDELINES

4. Rib-marks: Curved lines perpendicular to the fracture direction. When they are closely-spaced and distinct, it is an indication of high stress. When they are widely-spaced and faint, it indicates a low stress was present at the time of fracture.

5. Hackle lines: Lines parallel to the fracture travel. They are closely spaced and their appearance indicates the presence of a stress gradient at the time of fracture. These lines are found in areas of the glass that were in compression before fracture travel started.

Using these guidelines for analyzing fracture patterns in glass, time-consuming efforts to trace the cause of breakage can be eliminated, thereby reducing production losses and quality problems. High tensile stresses causing fracture may be due to permanent stresses introduced into the glass during lamp-making. They may also be due to temporary stresses caused by a large temperature difference between any two points in the glass or by a mechanical force acting on the glass.

In Fig. 2, a fracture pattern due to a temporary stress caused by mechanical shock is shown.

FIG. 2 Surface pattern of fracture caused by mechanical shock (40x)

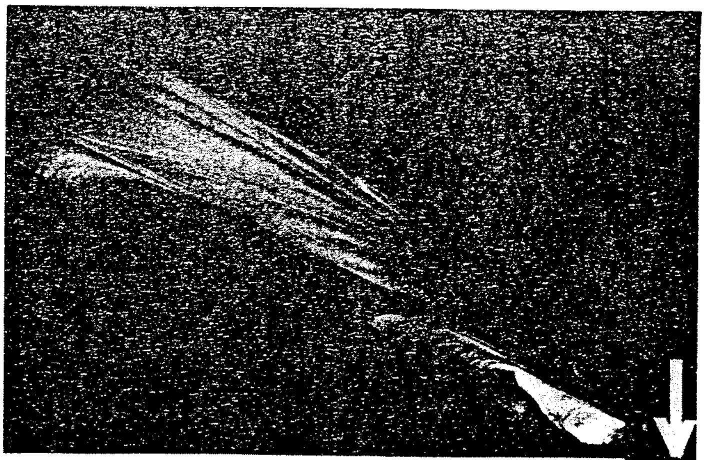


Fig.2 Surface pattern of fracture caused by mechanical shock(40x)

GLASS

8.4.1 GENERAL GUIDELINES

Examination of this pattern shows sharp, closely-spaced rib-marks radiating outward from the origin, which is referenced by an arrow. This source is on the inner surface of a bulb. It must have resulted because of a rapid heat-up of the outer surface or by mechanical force applied on the outer surface. Both forces would place the inner surface of the glass in tension. No pre-heating problems were present on the Sealex at that time, thereby eliminating this possible cause. Since the problem was narrowed to a mechanical shock as the cause of fracture, areas around the Sealex and Finishing machines were explored to find out where mechanical shock on the glass occurs. It was traced to the packer's position, where the lite-up socket was found to be improperly lined up and the metal shell caused this impact-type crack.

Figure 3 shows a fracture pattern caused by thermal shock during cooling of a lamp. Again notice the closely-spaced rib-marks, which indicate that a high stress level was present at the time of fracture.

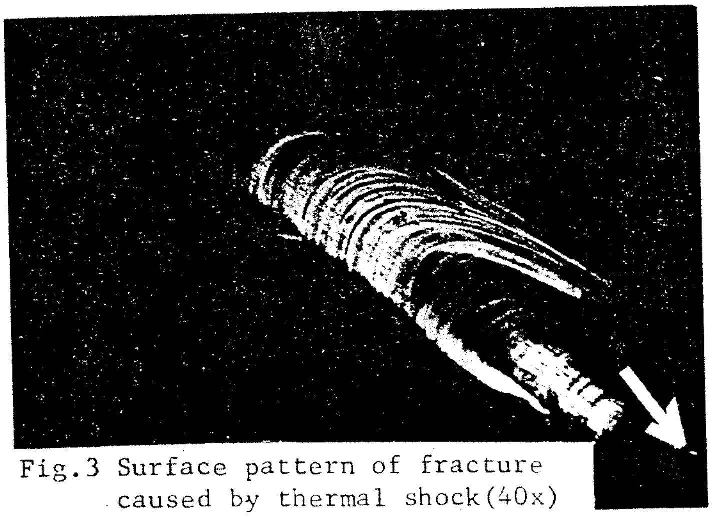


Fig.3 Surface pattern of fracture caused by thermal shock(40x)

8.4.1 GENERAL GUIDELINES

In this case, the source of the crack was traced to the outer surface of the bulb, just below the major diameter of the bulb. A mechanical force would have to be applied on the inner surface to create this fracture and this was highly unlikely on this bulb, so areas around the Sealex causing a thermal shock were studied. It was found that the metal cup holding the lamp during tipping-off of the exhaust tube was the cause of the problem and lowering the temperature of the exhaust bake-out oven reduced the thermal shock on the glass, to prevent further cracks from happening.

Figure 4 is an example of a fracture caused by a stone in the bulb.

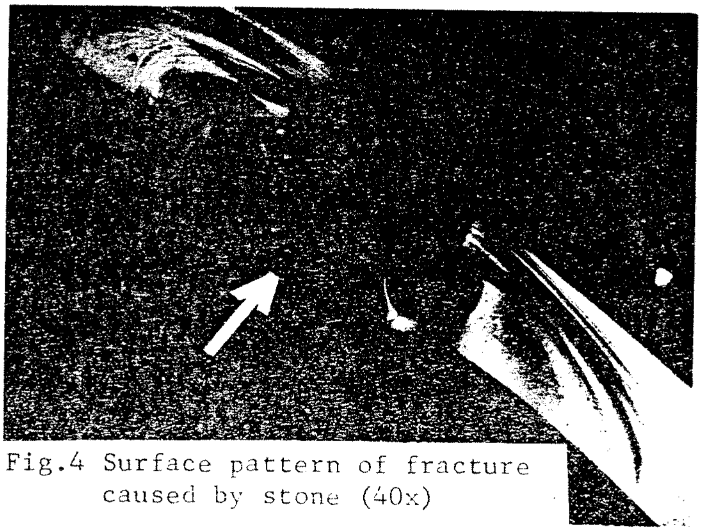


Fig.4 Surface pattern of fracture caused by stone (40x)

Again, tracing back along the concave side of the rib-marks from both directions, the source of fracture is determined to be the stone in the wall of the bulb.

8.4.1 GENERAL GUIDELINES

In Figure 5, a fracture surface due to high permanent stress in the bulb wall is shown.

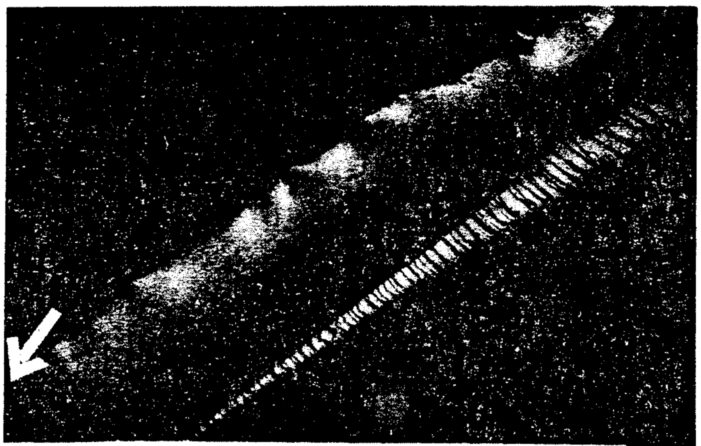


Fig.5 Surface pattern of fracture caused by permanent stress (40x)

This fracture is characterized by faint, widely-spaced rib-marks radiating outward from the origin and by the presence of hackle lines, indicating the presence of a stress difference between outer and inner walls. On tracing back along the concave side of the rib-marks, the location of the origin, shown by the arrow, was found. In this fracture, it was on the outer surface of the bulb, in contact with the metal carrier inserts on the Sealex. Proper fire setup on the Sealex minimized the permanent stress build-up in the glass wall area, which was in contact with the inserts, to reduce this type of fracture.

Using the general guidelines of fracture analysis and a sound knowledge of the incandescent lamp-making operations, fracture

8.4.1 GENERAL GUIDELINES

problems can be accurately and quickly solved. The examples shown above are typical of these fracture problems and highlight the effectiveness of this approach in reducing production losses and quality problems due to glass fracture.

8.5 Stress Measurement

Polarized light responds to strains within glass regardless of their origin so that polariscopes are used extensively for the control of residual stresses, which determine the effectiveness of annealing and tempering operations.

Photoelastic methods have distinct limitations as a means of determining stresses. In the case of two-dimensional stresses, the measured retardation represents the direct stress component only at certain points of the area viewed, such as at a free boundary. At other points where stresses exist in both principal axes, tedious analytical methods must be employed in order to evaluate these stress components. Techniques commonly used for the photoelastic analysis of three-dimensional stresses in plastic materials are not applicable to glass. Three-dimensional stress conditions in glass can be analyzed only where simple symmetry of geomettry and stress exist and require the use of complex analytical procedures. Because of these limitations, the use of polariscopes and polarimeters in the glass industry is largely as comparators for maintaining stress patterns and relative intensities determined to be satisfactory with empirical methods.

8.6 Effect of Time, Temperature and Moisture on Glass Strength

Glass will stand a load of perhaps 10,000 lb./sq. in. for a minute, but may fail at 6,000 lb./sq. in. if the load is left on overnight. No account of mechanical strength testing is complete unless at least a rough estimate is given of the duration of the test. This weakening of glass under continued load is known as "fatigue" or "static fatigue." It is to be distinguished from the failure of metals under long continued cyclic loading which is associated with the "work-hardening" we have previously mentioned.

The strength of most metals falls off rapidly with rising temperature. This is because thermal motion of the atoms facilitates the formation and motion of dislocations in the metal crystals. The temperature range in which this decline takes place and the seriousness of the loss of strength depend upon the structure of the metal crystals and the kind of bonds between the metal atoms. With glass, the effects of both time and temperature on the strength seem to be associated with the reaction of water on flaws in the surface. When we score a glass tube in order to break it at a predetermined point we moisten the scratch before applying force. When tested in a very dry environment, glass is appreciably stronger than in a normal atmosphere. One of the most convenient ways of eliminating the effect of water on measurements of the strength of glass is to carry on the tests at a very low temperature. When samples and surroundings are cooled with liquid nitrogen (-196°C.), essentially all water vapor is frozen out of the atmosphere.

8.6 Effect of Time, Temperature and Moisture on Glass Strength

Under these circumstances, not only is the glass stronger, but also the fatigue effect disappears. The glass bears indefinitely whatever load it sustains at the beginning of a test. As the temperature is raised in a normal ambient atmosphere, the strength decreases up to about 100°C. In this temperature region the strength of glass passes through a minimum and then increases until, in the annealing range, it again falls off as the glass rapidly becomes ductile. When the glass surfaces are stressed under circumstances where interaction with atmospheric moisture is impossible, the maximum in strength above 100°C. is not observed. Instead there is a progressive fall in strength as the temperature rises.

These effects of temperature and moisture on the failure stress for glass may, no doubt, be explained by the chemical action of water on the ≡Si-O-Si≡ bonds in the glass at the tips of flaw fissures and by thermal activation of the reaction of breaking these bonds.

8.7 Strength of Bulbs and Bottles

Bottles intended to hold carbonated beverages are subjected to internal pressure. In the case of soda water, pressures of 80 lb. sq. in. may sometimes be measured in the liquid, and siphon bottles are nominally charged with liquid at 180 lb./sq. in. The actual pressures are usually lower. They vary a great deal with the temperature, the gas (CO_2) tending to come out of solution and developing more pressure as the temperature rises. Theoretically, all bottles have an ample margin of strength to withstand these

8.7 Strength of Bulbs and Bottles

pressures, but in practice difficulties occur at times with flaws or local concentrations of stress. Flaws caused by rough handling, particularly when the glass surface is new and clean, drastically diminish the strength. A bottle which is overfilled, so that the contents expands and fills the whole space, may be exposed to very high pressure indeed. Impact stresses, which occur when the space above the contents is evacuated and the bottle is dropped on its bottom (water hammer) may also be very destructive. It is customary to test bottles intended to withstand pressure (technically known as pressure ware) by subjecting some or all of them to a hydrostatic test.

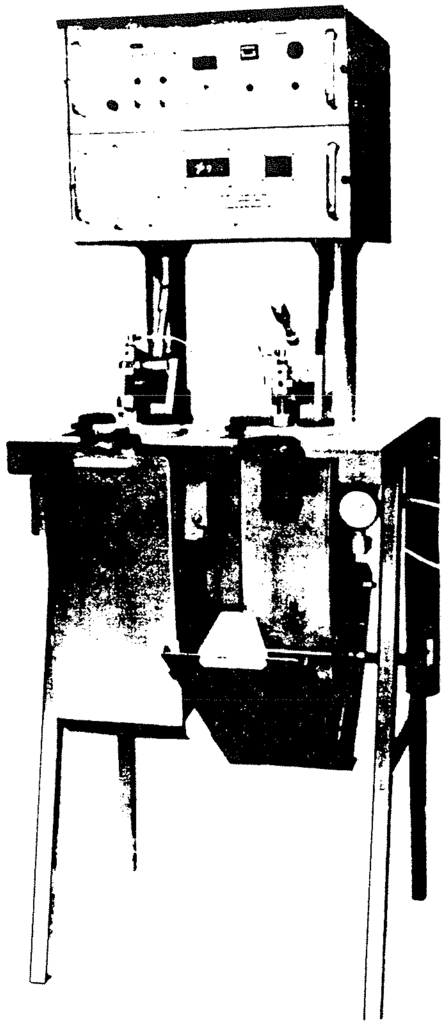
If a few bottles are tested, each may be tested to destruction, and the pressure at which each bottle broke recorded. Here again, the average breaking pressure is less important than the low end of the distribution curve of bursting pressures. We wish to be sure that the chance of finding a bottle which will fail under service conditions is so small as to be negligible. If all of the bottles are tested or a large number of them, it would not do to break them all, or nothing would be left to sell. They are, therefore, tested at a specified pressure (perhaps twice the working pressure) for a given length of time (usually one minute). The time factor is quite important and allowance must be made for the fatigue effect.

8.7 Strength of Bulbs and Bottles

A simple device for testing bottles under internal pressure employs a small plunger rod sliding through a rubber collar fitted to the neck of the bottle to be tested, which is filled with water. Weights laid in a holder at the top end of the plunger exert pressures upon the interior of the bottle, which are increased at timed intervals, usually 60 seconds, until breakage occurs or a specified maximum is reached. The plunger is rotated to eliminate friction. A metal shield protects the observer and catches the water and fragments when the specimen bursts. In a modern version of this device the application of pressure by a pump is controlled electronically so that testing is more rapid and precise. It would be highly desirable to subject all pressure ware to a qualifying test of perhaps twice the expected working pressure because of the hazards associated with flying glass when a bottle fails in service. The practical difficulties associated with testing between one and two hundred bottles per minute are self-evident but work is being done on an automatic device for such testing.

8.7 Strength of Bulbs and Bottles

Ramp pressure tester
for bottles
American Glass Research
Butler, Penna.



The data relating to bottle testing is similar for lamp testing. Par lamps are 100% pressure tested for lens seal failure. Gas (N_2) pressure is used for bulb testing. One of the realities which must be considered is that pressure testing is usually done at room temperature and lamp maximum internal pressures are reached at maximum bulb temperature. This can be a problem for a marginal bulb because the strength of the bulb decreases with increasing temperature.

8.8 Heat Shock Tests

Bottles, containers, and other types of hollow ware and table glassware may be tested for their power to resist heat shock by methods simulating conditions met in use. The pieces of ware, usually held in wire baskets, are immersed alternately in hot and cold water and the degree of endurance is estimated by the number of successive dips that can be endured, or the temperature difference that can be sustained without breakage. This test reveals residual strain in glass, defects such as stones, cords, checks, and bruises, as well as poor design of the piece with regard to variations in thickness, fillets, reentrant angles, and similar purely structural features. It is obvious that large and thick-walled pieces cannot be expected to endure heat shocks as extreme as those which may be applied to smaller and thinner articles. For technical glassware and baking dishes, whose thermal endurance must be high, this test may take the form of heating in an oven to a temperature above the boiling point of water, followed by immersion in cold water. For testing a glass per se, specimens are conveniently made by drawing cylindrical, uniform rods which will give more closely comparable results than pieces of ware of varying sizes and shapes.

Heat shock tests, because of the general distribution of the stresses induced in the article, are more efficient than any kind of purely mechanical test in weeding out defective ware. Down shock, which involves rapid cooling of hot ware, eliminates surface defects such as checks and bruises, while up shock (sudden heating) detects

8.8 Heat Shock Tests

stones buried in the glass, which may be too small to be found by normal visual inspection.

A more severe thermal shock test used for some lamp parts is the salt bath test. The salt bath is much hotter than boiling water and hence the shock is greater.

8.9 Glass to Metal Seals

Glass-to-metal seals or joints can be assigned generally to one of four types:

Type 1. "Matched" seals, in which the metal is sealed directly to the glass, the resulting stress in which is kept within a safe limit by selecting a glass and a metal of coefficients of thermal expansion and contraction closely alike.

Type 2. "Unmatched" seals, in which the thermal expansion of the metal differs from that of the glass, and the dangerously high stresses which would normally arise are avoided by using

(a) metal of small diameter;

(b) ductile metals which, by their yielding, give some relief to the stresses in the glass; or

(c) intermediate glasses and graded seals; the final seal between the metal and the last member of the intermediate glasses being of the "matched" type.

GLASS

8.9.1 General Requirements for Glass to Metal Seals

A metal which can be attached to glass to produce a gas-tight seal should conform to the following general requirements:

1. Its melting point must be higher than the working temperature of the glass.

2. Sufficient quantities of it, of specified thermal expansion coefficient, should be available in a clean state from the metallurgical point of view, i.e., as free as possible from non-metallic inclusions.

3. It must be sufficiently ductile to enable it to be formed into wire or strip without cracks, seams, laps or other mechanical defects.

4. The curves of thermal expansion of both metal and glass should, in the case of matched seals, follow one another closely over the same specified range of temperature.

5. No allotropic transformations, accompanied by marked changes in thermal expansion rate, should occur in the metal over the range of temperature to which it may be subjected, either in making the seal or during its subsequent use. This range may be as extensive as -50^{o} to $2000^{o}C$.

6. Any layer of oxide formed during the process of making the glass-to-metal seal should adhere firmly to both metal and glass.

7. High electrical and thermal conductivity are advantageous if the metal has to carry a substantial electric current; for otherwise the heating effect when current flows may result in a substantial increase in strain.

GLASS

TABLE 8.9.1

Properties of Metals suitable for Sealing to Glasses of High Thermal Expansion (Soft Glasses). Determined on soft wire about 1 mm. in diameter.

Metal.	M.Pt.*	Maximum Operating Temp.		$\alpha \times 10^6$ (20°—350°).	Ultimate Strength (Tons/sq. in.).	Yield Stress (Tons/ sq. in.).	Elongation (% on 100 mm.).	Spec. Elect. Resistance (microhms/ cm.).	Thermal Conductivity * (cals./sq. cm./cm./ °C./sec.).
		In Vacuo.	In Air.						
Platinum	1750	1600	1400	9·25	8—9	ca. 2	30—40	10·6	0·166
Copper	1083	400	150	17·8	16—17	9—10	30 (50—60)	1·75	0·92
Nickel	1452	900	400	14·5	34	16	25 (35)	7·5—10·0	0·14
Iron	1530	500	200	13·2	15—17	8	30 (40—50)	9·6	0·17
(Platinum substitute) "Dumet" alloy. (43% Ni–Fe alloy sheathed with copper)	—	400	150	ca. 7·1 † ca. 9·0 ‡	30—34	20—23	25 (40)	5·7	—
50% Ni, 50% Fe alloy	—	1000	—	9·5	35—36	22—25	25—28	49	0·025
26% Cr–Fe alloy	—	1000	1000	10·2	39—41	28—30	18—20 (35)	68	0·03
42% Ni, 52% Fe, 6% Cr alloy	—	700	—	8·9	30—32	16—18	25	94	—
"Fernichrome" (37% Fe, 30% Ni, 25% Co, 8% Cr)	—	—	—	10·0	—	—	—	—	—

The elongation figures in brackets were determined on specimens of larger diameter over a gauge length = $4\sqrt{\text{area}}$.
* Taken from the literature.
† Longitudinal.
‡ Radial.

TABLE 8.9.2

Properties of Metals suitable for Sealing to Glasses of Low Thermal Expansion (Hard Glasses). Determined on annealed wire about 1 mm. in diameter.

Metal.	M.Pt.	Maximum Operating Temp.		$\alpha \times 10^6$ (20°—350°).††	Ultimate Strength (Tons/sq. in.).	Yield Stress (Tons/ sq. in.).	Elongation (% on 100 mm.).	Spec. Elect. Resistance (ohm/cm.).	Thermal Conductivity ** (cals./sq. cm./cm./ °C./sec.).
		In Vacuo.	In Air.						
Tungsten	3350	3000	300	4·4	99	85	4	5·6	0·38
Molybdenum	2450	2000	200	5·5	47	41	15—20	4·8	0·35
98% W + 2% Ni	—	900	300	4·9	—	—	—	—	—
50% W, 50% Mo Alloy	ca. 2800	2000	200	5·0	80	74	25—30	8·6	—
G.E.C. Heavy Alloy	ca. 1450	—	300	5·6	40	35	3—4	11·6	0·25
84% W, 12% Ni, 4% Co	—	—	—	6·8	—	—	—	—	—
"Fernico I" (54% Fe, 28% Ni, 18% Co)*	ca. 1450	ca. 1000	ca. 600	4·5	40	28—30	24	46	—
"Fernico II" (54% Fe, 31% Ni, 15% Co) *	ca. 1450	ca. 1000	ca. 600	5·0 (5·1) ‡	32—36 (35·5) ‡	25 (24·7) ‡	25—33 (31) ‡	43·8	—
"Kovar" (54% Fe, 29% Ni, 17% Co) †	ca. 1450	ca. 1000	ca. 600	4·7	38—40 (39) ‡	25 (27) ‡	32 (26) ‡	44	0·04
Tantalum	2800	2500	—	6·5	—	—	—	15·5	0·13
43% Ni–Fe Alloy	ca. 1450	ca. 1000	ca. 600	5·2	38—40	24	22—25	65	0·025

* *J. App. Physics*, 1941, **12**, 698.
† Stupakoff Ceramic and Manufacturing Co., Latrobe, Penn., U.S.A.
‡ The figures in brackets were determined on specimens of iron–nickel–cobalt alloys made by pressing and sintering pure metal powders and subsequently fabricating into wire.
** Taken from the literature.
†† The usual symbol α is used throughout in referring to the linear coefficient of thermal expansion.

All temperatures, unless otherwise stated, are expressed in degrees Centigrade.

8.9.1 General Requirements for Glass to Metal Seals

8. Ease of joining to other metals by welding or soldering is desirable and often essential.

Tables 8.9.1 and 8.9.2 show properties of metal used for glass to metal seals.

8.9.2 Bonding Mechanism

A good bond between glass and metal can be obtained only if some interaction takes place on their contact surfaces. The nature of the interaction (its mechanism) is not theoretically explained for all the glass-metal seals. Experimental results show that in the usual glass-metal seals the adhesion is based either on a direct glass to metal bond or on a glass-(metal) oxide-metal bond. In the direct glass to metal bond the metal surface adheres to the glass without any intermediate layer. This kind of seal can be vacuum-tight but the bond is usually relatively weak. The glass-metal seals are mechanically stronger if between the metal and the glass an oxide layer is formed. In fact the oxide layer contains a graded series of oxide mixtures from the oxide of the metal to those forming the glass. The fact is best illustrated by the seal of iron-nickel alloys in lead glasses, where the iron takes the place of the lead in the glass layers near to the joint.

The reliability of the glass-metal bond is determined by the thickness of the oxide film, the uniformity of the layer and the kind of oxides present. The oxide layer must be so thin as to be able to follow elastically the displacements of the glass, without

8.9.2 Bonding Mechanism

building up stresses. Thick oxide layers have usually a porous outer shell. Even if the glass adheres to this shell, the joint will not be tight and the seal not strong enough. The oxide layer should be continuous and should have a uniform thickness and the same composition over the whole seal.

8.9.3 Color of Seal

The colour of the glass-metal seal is generally a good indication of the bond (the quality of the seal), as most of the metal oxides give strong colours when dissolved in glass. For most of the seals the colour indication can show if the seal is reliable, but in some cases this is not a definite indication whether the seal contains or does not contain the desired oxide (e.g. tungsten).

Generally over-oxidized seals have a dark colour, and under-oxidized seals a very light appearance. In copper to glass seals the colour of the seal shows without doubt if the bond is made by means of the metal (gold-red), the cuprous oxide Cu_2O (purple) or the cupric oxide CuO (black), but the colour does not show if the layer is thin or thick, i.e. if the joint is tight and strong.

The composition of the glass can also influence the colour of the seal. Thus, tungsten sealed in glass which contains lithium does not show the characteristic brown-yellow of the tungsten-glass seals, but a bluish colour due to the lithium tungstate formed.

The colour indication is very useful in those cases where the colour differs visibly according to the degree of oxidation.

8.9.3 Color of Seal

Thus the FeNiCo seals show a silverish metallic colour if the oxidation is not strong enough for a good seal, a grey to brown colour for the correctly oxidized seals, and a black appearance if the metal was over-oxidized.

Platinum can be sealed in glass only without oxides, since it does not form them; thus the platinum-glass seal has a metallic appearance and a limited strength. Copper can give very adherent seals, if the oxide is Cu_2O and its thickness is the proper one. In an oxygen-free atmosphere, copper can be also sealed to glass by "metallic bond" but these seals are never as strong as those with oxide layers. The correct colour of copper to glass seals varies thus from gold-yellow to purple. Nickel can adhere to glass, with a metal or oxide bond. The proper colour of an oxide bond is for nickel-glass seals, green-grey. Iron is a very promising metal for glass-metal seals, but its use is restricted due to the difficulties presented by its various oxides. Tungsten and molybdenum can give metallic bonds, but the seals having an oxide layer are preferred despite the difficulties in constructing them. The colour of an adequate tungsten-glass seal is from golden yellow to brown if sealed in glasses containing sodium or potassium, blue if the glass contains lithium and grey-brown in lead glasses. The molybdenum seals are generally brown. Chromium forms an oxide bond and produces very strong seals, which are dark green in colour. The FeCr glass seals are brown-green, those with FeNiCo grey or blue

8.9.3 Color of Seal

and FeNiCr seals are brown or brownish-green. In order to make successful seals with iron containing alloys, the sealing technique tends to form on the surface of the alloy only chromium or nickel oxides since the iron oxides present the difficulties discussed before. These oxides are easily formed in the seal when FeCr of FeNiCo is used, but with FeNiCr alloys the desired oxides must be formed by a previous chemical treatment (preheating in wet hydrogen).

The glass-metal bond is also influenced by the gases occluded in the metal. At the temperature of the sealing process, these gases evolve from the metal, but they cannot leave the glass, and are trapped on the glass metal border, forming bubbles.

8.9.4 Glass to Metal Seal Test

A good (but destructive) test for the adhesion is to break the seal; if a thin layer of glass remains on the metal, the adhesion is strong enough for a reliable glass-metal seal.

Figure 8.9.4.1 shows some examples of glass to metal seals.

GLASS

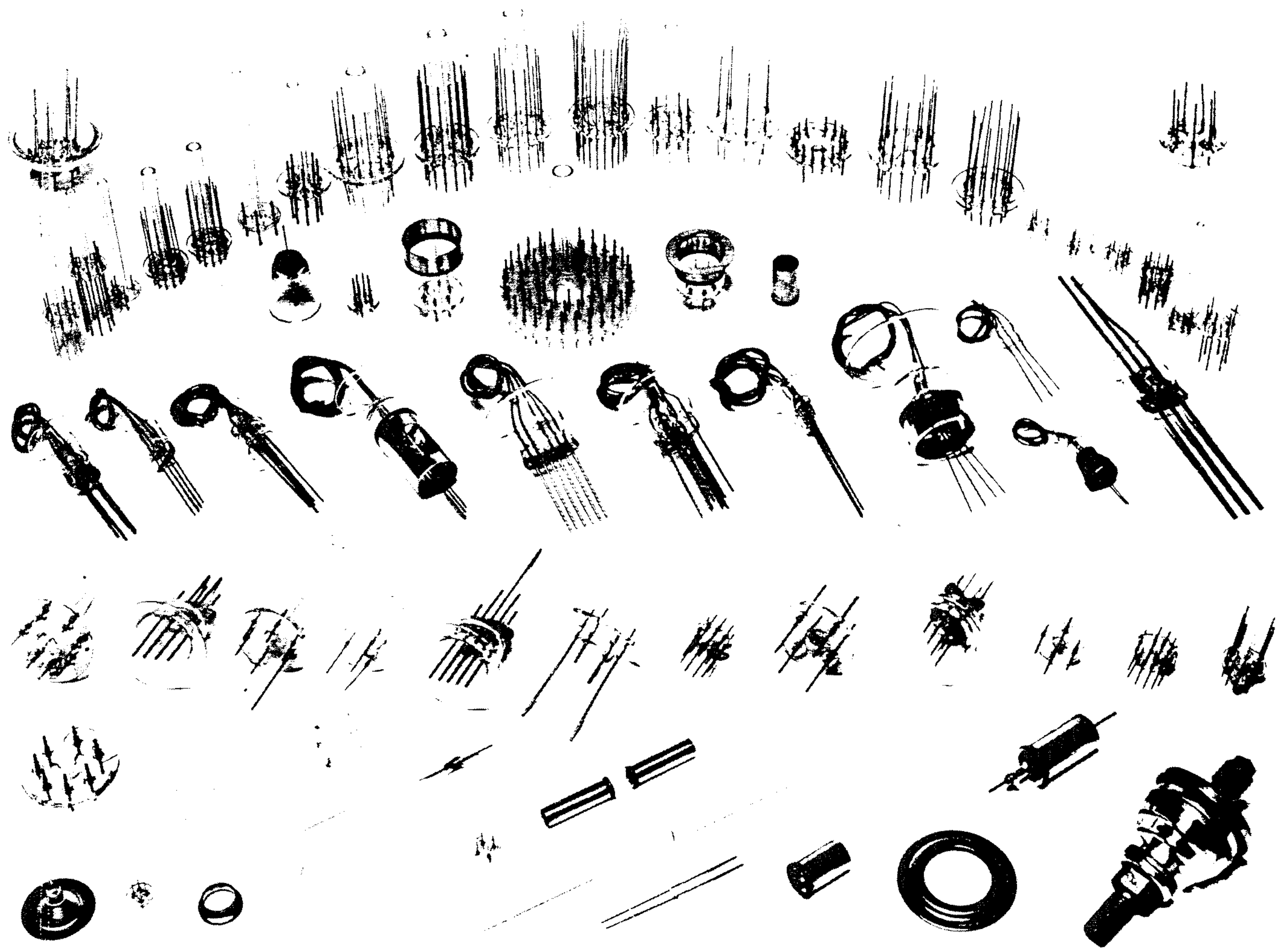


FIGURE 8.9.4.1

GLASS

8.10

References for Additional In-depth Information

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2. Stresses in Incandescent Lamp Glass by Peter Caleshu, GTE Sylvania, Loring Avenue, Salem, MA. 01970
3. Fracture Analysis of Glass by Peter Caleshu, GTE Sylvania, Loring Avenue, Salem, MA 01970
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GLASS SEALING

9.1 Methods of Heating

Glass sealing refers to joining two or more pieces of glass together by fusing the glass to glass joint. The method of heating is usually a gas-air or a gas-air-oxygen flame.

Temperatures of 700 to 1150°C can be obtained with the usual combustible gases and air; for temperatures up to 1700°C oxygen must be added in the flame and if temperatures up to 2000°C are required hydrogen plus oxygen should be used.

The shape of the flame is determined by the construction of the burner, the type of the gas used and the pressure (rate of flow). With the appropriate design, strong or weak, sharp or rounded, hard or soft, long or short flames can be produced. Their shape is determined by the work to be done. For manual work, hand torches, or blowing burners are used. For mechanical work the burners are mounted on glass blowing lathes, sealing machines, stem making machines, etc.

For special applications, glass to glass seals can be made using electrical heating methods: resistance welding, high frequency induction or dielectric heating. For glass butt seals where the heating of a wide zone is to be avoided, a sort of resistance welding can be used. This consists in using two torches with sharp flames, placed opposite to each other on the two sides of the glass pipe. After the edges of the pipes which are to be joined have been first heated with the flame, a high frequency current (1000 V, 10^5-10^7 cycles) is passed through the torches. The gases from the flames

9.1 Methods of Heating

are now used as current lead-throughs, and the preheated glass edges have enough conductivity to act as a resistor. The edges are heated quickly by the current, to a high temperature (1000°C) without heating the rest of the glass tube. The time required for the sealing by this method is only a tenth to a hundredth from that required in flame sealing. It must be noted that if the two glasses to be sealed have different electrical conductivities, the part having the higher resistance must be preheated at a higher temperature to obtain the conductivity required for the further electrical heating.

Instead of using flames, a spark discharge can be used, directed along the surface of the glass, in the region where the heating is required. When the resistance of the glass becomes smaller than that of the air gap along the surface, the discharge path will move into the body of the glass producing a uniform heating.

9.2 Types of Seals for Incandescent Lamps

There are basically four types of seals used for incandescent lamps.

1. Bead Seal - Microminiature lamps
2. Butt Seal - Subminiature and Miniature lamps
3. Wedge Seal - Subminiature and Miniature lamps
4. Stem Seal - Miniature and Large GLS lamps. Stem seal lamps are also called flare seal and flange seal lamps.

9.3 Bead Seal Construction

The bead seal is used for microminiature vacuum lamps. The seal is glass to glass. The lamp construction process is as follows:

1. A two lead beaded mount is manufactured. The leads are unborated dumet. The bead is made from clear glass tubing or same glass as bulb.

Figure 9.3.1 shows such a mount

Figure 9.3.1

The beaded mount is chemically cleaned to remove any oxides from leads.

2. The filament is attached to the flattened leads usually by pressing the tungsten into the copper. Clamping is also possible.

3. The mount assembly is inserted into a domed tubular bulb. The mount is fixed in the desired position by tacking the lead to the bulb by applying a small flame to the bulb with the lead touching inside of bulb.

4. The bulb which is about 25 mm long is inserted into a compression head on a trolley or rotary exhaust. The heat for the seal is radiant heat from a nichrome resister which surrounds the bulb in the area of the bead inside bulb. The heater is energized to a preheat level to outgas the bulb and bead. This preheat process

9.3 Bead Seal Construction

is done with air in the bulb. For reasons which are not entirely clear, the air lightly oxides the copper clad leads and this low oxide acts as a getter during the final sealing operation. Lamps made with N_2 during preheat or without leads are nearly always "gassy" lamps. The preheat time is about one minute.

5. After preheat the lamp is evacuated. The air passage from bulb to pump is around the bead. The fit of the bead to bulb should be loose but with only a few mils clearance. The pumping system consists of a mechanical pump, diffusion pump and cold trap. The vacuum in the lamp must be as high as possible during sealing and after seal is complete. The pre-heat can remain on during pump out as long as the bulb does not start to collapse due to atmospheric pressure.

6. When vacuum has reached 1 micron or less, the voltage to heater is raised to sealing level. The bulb shrinks around the bead and fuses to the bead. The seal is now complete. Over heating cannot be tolerated because too much gas will be evolved into the lamp and also because the bead will become soft and leads will move and destroy filament geometry. Figure 9.3.2 is completed bead seal lamp.

9.3 Bead Seal Construction

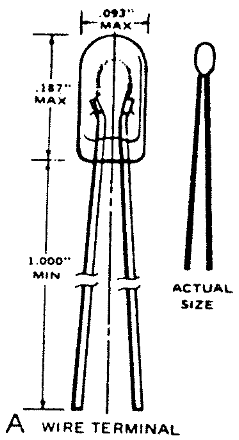


Figure 9.3.2

7. After sealing, the excess glass below seal is removed by scoring and breaking.

9.4 Butt Seal Construction

The butt seal construction is used for subminiature and miniature lamps up to G-6. The leads are nearly always 10 mil borated dumet. The butt seal is a combination of glass to glass and glass to metal together with a restricting process to form the tip-off area. The lamp construction is as follows:

1. A beaded mount assembly is constructed on a mount mill. The bead could be cut from tubing but is usually a pressed and sintered frit bead and often is dyed for color coding for mount identification and sometimes lamp identification when no base is used - where a lamp is soldered direct to a circuit board for example. Figure 9.4.1 shows a complete beaded mount.

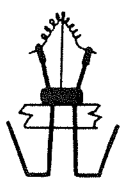


Figure 9.4.1

9.4 Butt Seal Construction

2. The beaded mount is inserted into the neck of the bulb and hung by the lead wires as in Figure 9.4.2.

Figure 9.4.2

3. The bulb and mount is held in the sealing head by vacuum. The piece of glass tubing is held above and in line with the bulb. The tubing is the same O.D. and I.D. as the neck of the bulb as shown in Figure 9.4.3.

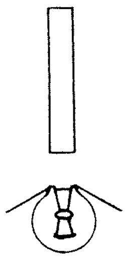


Figure 9.4.3

The butt seal tubing and bulb rotate together. The mount is prevented from rotating in the bulb by guides at ends of the leads. The mount is not tightly held - only restricted.

9.4 Butt Seal Construction

4. Sharp flames are played on top of the bulb neck and also end of the butt seal tube. The fires on the bulb neck are critical because they must heat glass and leads but not burn the dumet leads. After heating, the butt sealing tube is lowered to touch the bulb neck and both the neck and tube are heated together. The lead is somewhat protected by conduction of heat from the seal by the cooler parts of the lead. The butt seal tubing is moved up and down slightly to "work" the seal and eliminate reentrant angles.

5. After the seal has been "worked", the flame is directed at an area about 1/8-3/16" above the seal. When the glass tubing has softened, the tubing is pulled up slightly to restrict or neck the tube for tipping. The completed assembly from sealing is shown in Figure 9.4.4

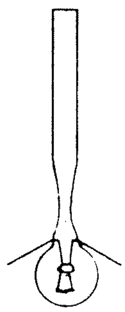


Figure 9.4.4

9.4 Butt Seal Construction

6. Before inserting the exhaust head, the bulb assembly is removed from the vacuum cup and held by the exhaust tube. At this time, the entire assembly is heated to outgas the bulb assembly. While the bulb was held in the sealing cup, the dome of bulb was cold. After exhaust the lamp is tipped and ready for basing or soldering directly to circuit board, etc. Figure 9.4.5 shows some complete lamps.

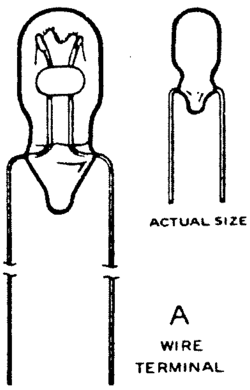


Figure 9.4.5

9.5 Wedge Seal

The wedge seal is a combination glass to glass seal and glass to metal seal. The leads are nickel plated dumet and usually about 12 mils diameter. The exhaust tube is incorporated in the seal such that the hole in the exhaust tube is kept open. The seal is made with the opening of the bulb down and the mount assembly held by the leads in a weld block. It is necessary that the seal area of the nickel plated dumet leads be oxidized during the sealing process before seal is complete. The general wedge seal process is as follows:

9.5 Wedge Seal

1. A beaded mount assembly is prepared on a mount mill. The leads are formed to a different configuration than butt seal lamps. Figure 9.5.1 shows a complete beaded wedge mount assembly.

Figure 9.5.1

2. The first item to be loaded on the sealing machine is the exhaust tube. It is held by grippers and extends through and above the weld block. The mount assembly is loaded next. The top of the exhaust tube is between the leads. The mount is held by the leads. The bulb is loaded last and is held by V jaws with bottom opening about 1/32" above the top of the weld blocks.

3. Fires are played on both sides of the bulb seal area. The bulb protects the exhaust tube from direct heat. The heating process must be progressive so that the bulb can be pressed and fused to the exhaust tube and yet not overheated so that the bulb glass crawls and droops. The glass geometry determines the quality of the press.

4. After sufficient heating, the sealing area is mechanically pressed by opposing jaws. The jaws have a relief in the middle so that the exhaust tube is not pressed. The complete seal can be made with one press but usually two presses are used. The second

9.5 Wedge Seal

press is used to obtain final shape of the press. The press has a projection which forms a horizontal groove on both sides of the press. This groove is used to hold the finished lamp in a socket. Figure 9.5.2 shows a complete lamp assembly ready for exhaust.

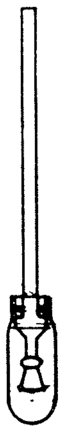


Figure 9.5.2

5. After exhaust, the lamp is tipped at the junction of the exhaust tube and press. A complete lamp is shown in Figure 9.5.3.

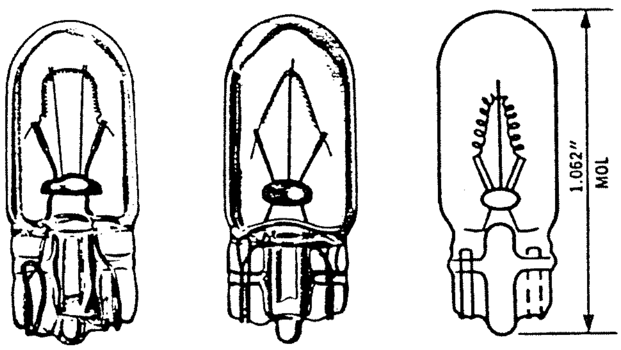


Figure 9.5.3

9.6 Stem Seal

The stem seal is a glass to glass seal. The bulb is sealed to the flare of a stem mount. Most stem seals are of the "drop seal" type. In this seal, excess glass in the neck of the bulb is "dropped" off after the seal is made. Figure 9.6.1 shows the inserted stem mount and bulb. The bulb is supported by its major diameter with the neck hanging down. The mount rests on the sealing pin. The sealing pin has a passage for air up through pin and exhaust tube and another passage which by-passes the exhaust tube and blows out the side of the sealing pin.

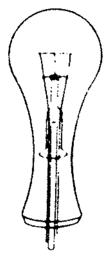
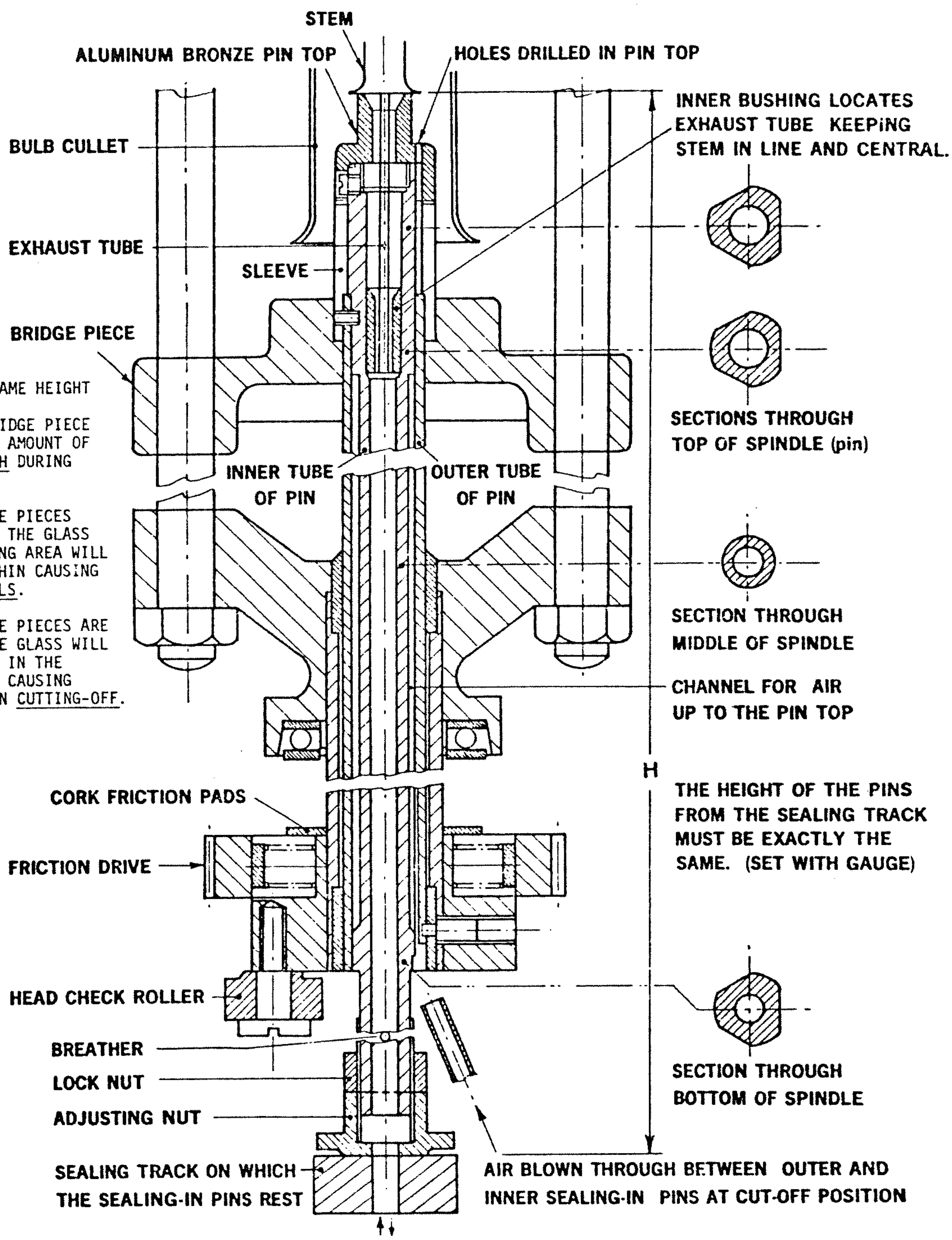

BULB AND MOUNT READY FOR SEALING

Figure 9.6.1

Figure 9.6.2 is typical sealing head. (See following page.)

DETAILS OF SEALING-IN MACHINE HEAD
SEALEX GROUP



1. SET ALL AT SAME HEIGHT
2. HEIGHT OF BRIDGE PIECE CONTROLS THE AMOUNT OF <u>GLASS STRETCH</u> DURING <u>SEALING-IN</u>.

   IF THE BRIDGE PIECES ARE TOO LOW, THE GLASS IN THE SEALING AREA WILL BECOME TOO THIN CAUSING <u>HOLES IN SEALS</u>.

   IF THE BRIDGE PIECES ARE TOO HIGH, THE GLASS WILL BE TOO THICK IN THE SEALING AREA CAUSING DIFFICULTY IN <u>CUTTING-OFF</u>.

A. TO ALLOW EXPANDED AIR TO ESCAPE FROM THE LAMP DURING SEALING-IN THUS PREVENTING THE GLASS "BALLOONING" OUT IN SEALING-IN AREA.

B. TO BLOW AIR THROUGH THE SPINDLE AND INTO THE LAMP AT THE NECK FORMING POSITION.

Figure 9.6.2a

KEY POINTS

SEALING-IN PINS

1. All set to same height.
2. Pin must move freely up and down in key way.
3. Pin tops must be in good condition.
4. Free air access through center of pin and sealing track.
5. Free air access through inner tube and outer tube. See that small holes in pin top are clear.

SEALING-IN CRADLES

1. The correct cradles for bulb size and/or shape.
2. Set all cradles level and at same height. Check height to give correct sealing - in length of lamps.

BRIDGE PIECES

1. All set to same height and level (height can be varied to give correct glass thickness at the sealing area.)

FRICTION DRIVE

1. Check to see that heads are revolving. (If not, check friction pads and springs).

Figure 9.6.2b

9.6 Stem Seal

The sealing-in process is as follows:

1. After having fed the mounted stem and bulb, heat is applied to the outside of the bulbs. The gas burners must be set so that the jets are practically horizontal and in the area of the pin top. It is important to see that only a small area of glass is heated, otherwise the glass will flow into the area where subsequent cut-off takes place, making this operation very difficult as the glass will have thickened in this area.

At speeds of over 1,500 per hour accurate flame setting is very important. With the application of heat the glass will be forced in, touching the flange. At the same time, the cullet end of the glass will drop on to the platform and the weight of the cullet will stretch the glass in the sealing area. This glass will also touch the base of the pin top, forming a 'pocket' between the flange and the top of the base of the pin top. Figure 9.6.3 shows the drop-seal general process.

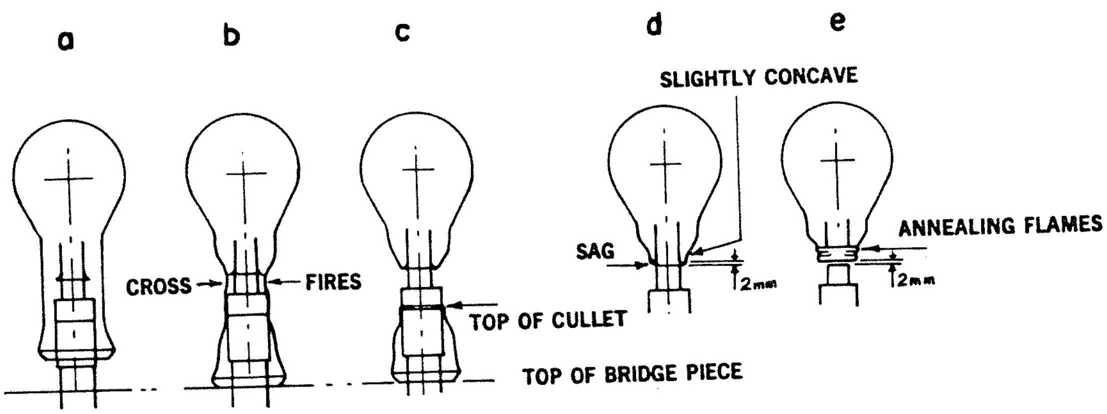


Figure 9.6.3

9.6 Stem Seal

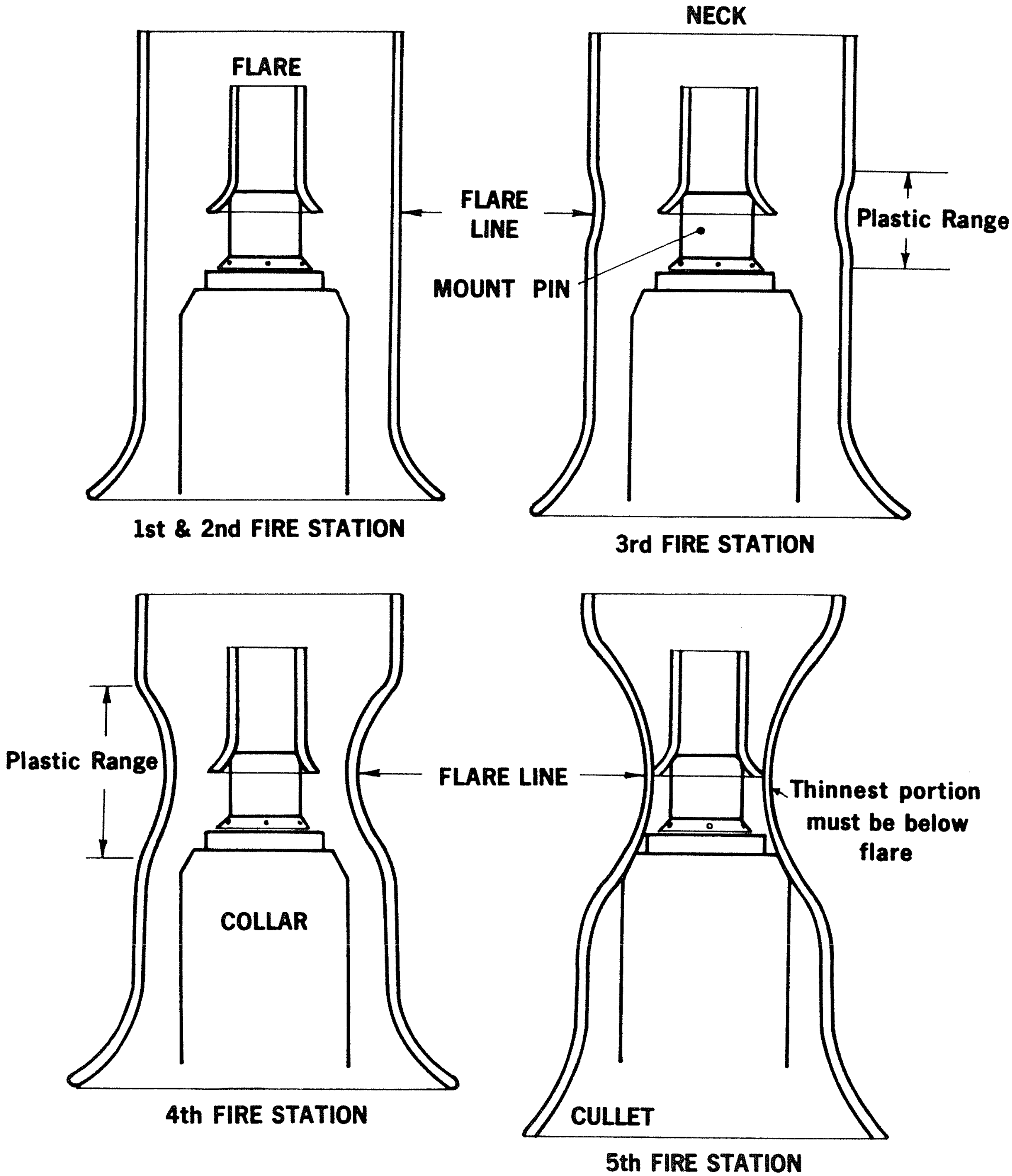
As the bulb is heated the air inside the bulb will expand. This will escape through the hole in the stem of the lamp, down the centre of the sealing pin to atmosphere, thus balancing the pressure of the air inside the lamp with atmospheric pressure. This prevents the glass from blowing out in the heated area.

THE DIMENSIONS AND SHAPE OF THE PIN TOP ARE VERY IMPORTANT.

The relationship between pin top diameter and flange diameter is important for sealing-in any type of lamp. Using flanges of 20 mm. diameter, a diameter of 12 mm has been found to be ideal. The length of the top part has been found to be ideally 10 mm. The material from which the pin tops are made is also very important. Aluminum Bronze is an ideal metal as it has good heat resisting properties and glass does not stick to it.

The sealing to the flange should be completed two stations before the 'cut-off'. In the 'cut-off' position flames set horizontally on the inside and outside of the machine cut through the glass just below the seal. In this position air is blown through the sealing-in pin (between inner tube and outer sleeve through the small holes in the pin top). This keeps the glass clear of the metal pin top, maintaining the pocket, and easy for the flames to cut through the glass. The cullet (waste) is later cleared from the head with compressed air.

INCANDESCENT SEALEX PRACTICE



Bulb Shape at various fire stations

Figure 9.6.3

GLASS SEALING

After 'cut-off' and before the lamp passes into the neck moulding position the seal is well melted. Passing from the position before the neck-mould the rail on which the pin rest drops suddenly 3 mm. This allows the glass seal to sag and the neck to concave slightly (see Figure 9.6.3d).

2. At the moulding position the two halves of the mould close around the seal and air is blown up the centre of the sealing pin into the lamp, blowing the glass into the mould.

Figure 9.6.4 shows some typical seal shapes after moulding. The grooved area in Figure 9.6.4 b is to capture basing cement and improve torque test data.

The lamp after leaving the moulding position should have a slight trace of color over the heated area of the glass. Absence of color at this position denotes lack of heat at the time of moulding, glass not plastic enough.

If glass fails to retain its shape after leaving mould position, and sags, it shows glass is too hot going into the mould. This condition affects basing.

If glass or cullet drops too fast and binds around collar of sealing pin, the glass is too thin.

The cooling of glass on sealing pin collar will cause contraction and consequent shattering of cullet, spraying operator with flying glass or broken glass will fly to and adhere to mould or lamp.

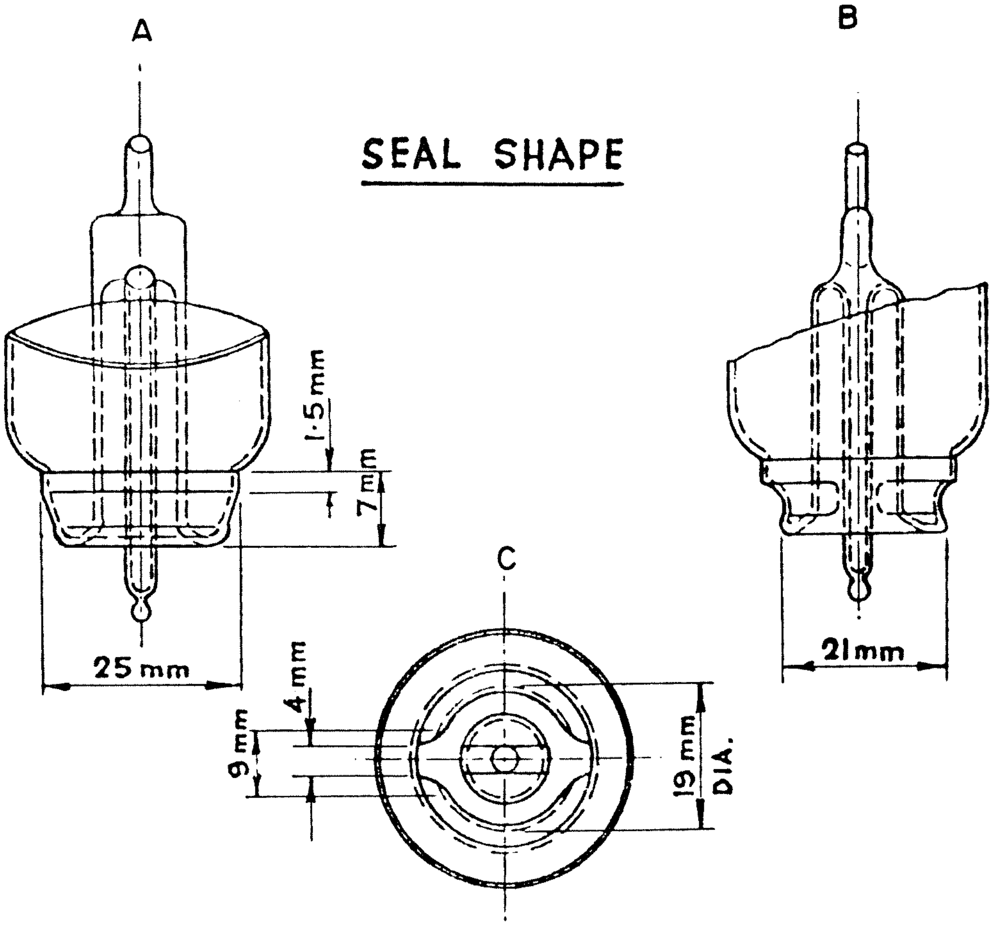


Figure 9.6.4

3. Moving from the moulding position, the pin drops suddenly 3 mm. This clears the metal away from the glass and allows the seal and neck to be annealed. This annealing by gas flames takes place in the next positions.

During the sealing-in operation heat is also applied to the bulbs (Heat distribution burners). Heat is also applied to the crown of the bulb to 'burn-in' the branding stamp. The overall temperature of the lamp is important, especially if the cold-pumping system is applied.

9.7 Key Points in Setting Up a Stem Seal Machine

a) The bulb cradles must be set at the same height.

b) The sealing-in pins must be all exactly the same length, and so set that the top of the pin top is 1 mm. above the base of the seal shaper.

c) The adjustable platforms must be all set at the same height.

d) Great care must be taken in setting the seal shaper moulds. They must meet exactly and be so set that the pin tops are exactly in the centre. Any slight imperfection on the surface of the moulds can cause the glass to crack at a later stage. Misalignment of the moulds can have the same effect.

e) Air clearances must be maintained in the sealing-in pins.

4. The drop seal is now complete and lamp assembly is ready for exhaust.

9.8 FLOOD FIRES AND TEMPERATURE CONTROL

On each machine there are so-called flood fires (Fig. 3) that are mounted between various sealing-in fire stations. These flood fires are used to heat the bulb in a uniform manner to remove contamination in the bulb before the bulb has reached the seventh sealing or cutting-off fire. If the heat has not been uniformly distributed over the bulb the contaminants may pocket or trap within the bulb.

If these contaminants are not effectively driven out, they definitely affect the life of the lamp. Unless there is some positive control over the bulb in production, this defect will not generally be ascertained until complaints begin to come in from the ultimate consumer. This means that there is a period during which bulbs are being made where all lamps made during that period may be defective, with no way of knowing into whose hands all of these lamps may go. For this very reason, the temperature control bulb, to be effective, must be run through on each machine at least once a shift.

This is an intangible defect that cannot be controlled in any other way except through the use of a temperature control bulb. Without the use of this control bulb, it is mere guess work as to whether the lamp is good or not. It may be good enough to get by a routine inspection, but fail in its ultimate use before its life expectancy has been reduced.

9.8 FLOOD FIRES AND TEMPERATURE CONTROL - (CONTD.)

The temperature control bulb corresponds to the size and shape of the bulb being run and is an exact duplicate of it with the addition of a color dye equally distributed over the inside of the bulb. The dye changes its color from a brown to a bleached out gray with the application of heat to the outside of the bulb. If the heat is of correct intensity and equally distributed over the globe section of the bulb the color is bleached out uniformly. Failure to distribute the heat evenly over the globe will leave the bulb spotty. These spots show the portions that must be given more heat.

In setting flood fires on bulbs, the temperature control bulb should be heated so that the globe end of the bulb will be completely bleached out.

After this position the heat must be maintained on the upper half of the globe end until the neck moulding position is reached. If the heat is increased on the bulb by the flood fires, the expanding air in the globe will be unable to escape through the vent hole in the mount and track fast enough to prevent the pliable neck of the bulb from blowing out with the air pressure inside the bulb.

If the flood fires allow the upper half of the bulb globe to cool, it creates a vacuum pulling the hot air in the bulb neck and collapsing the formed end of the bulb.

9.8 FLOOD FIRES AND TEMPERATURE CONTROL - (CONTD.)

In either the blowing or the collapsing of the neck, damage has been done to the seal at the flare.

If bulbs blow out or collapse after the cut-off station, either the track is dirty and not allowing the air to escape through the vent, or the flood fires on those stations following the cut-off are not in balance with the fires at the formed neck.

The second part of this means that if the heat of the forming fires drives the neck in, there must be a corresponding slackening of the flood fires to prevent the over-expansion of the air in the bulb; or a blowout will occur causing pinched seals.

If the forming fires are not hot enough to maintain the plastic form and the flood fires are heating the same as at the preceding station, the bulb shoulder will collapse.

In other words, the air in the bulb must be uniformly heated or pockets will result. The location of these pockets will determine whether the bulb will blow out or in. The final stations of both flood and sealing fires are merely holding fires. The bulb should be fully formed before the cut-off, and then held in that shape for the neck mould.

On vacuum type bulbs keep flood fires as hot as possible without burning the getter. To reach this point the heat is increased until the getter burns, then slightly back off the heat making sure the getter will not burn. Check with control bulb. The purple color should then be bleached out to a definite pinkish white.

9.9 COMMON PROBLEMS AND PROBABLE CAUSE

1.	Cracked bulbs	Heat applied too suddenly. Mechanical shock. On occasions inherent strain in the bulbs (for example - Colour glazed bulbs)
2.	Glass blowing out in sealing Area when melting.	Insufficient clearance through centre of sealing-in pins and holes in sealing track to allow the expanded air free and easy access. (Usually blocked pins and blocked holes in track). No hole in pinch (S.M.)
3.	Difficulty in "cutting off"	Too great an area of glass melted above the flange, or glass too hot which causes glass to flow down and thicken in the "cut-off" area. Bridge pieces set too high, not allowing the glass to thin out sufficiently. Blocked air holes in pin tops, pins not all set at the same height. "Cut-off" burners not burning properly or not set correctly. Air blowing pipe not in correct position. Check air flow.
4.	"Wings" on Seals.	Insufficient heat on heat distribution burners in EARLY STAGES of sealing to enable air in lamps to expand and escape. Insufficient clearance through centre of sealing-in pins and holes in sealing track to allow the expanded air free and easy access. The seal should form into a concave shape when the sealing-in pin drops 2 mm. as it leaves the seal heating position. The pin not dropping 2 mm. (check that pins are free to drop easily). The glass sagging down at the seal heating position (the head in this position must take at least ½ turn, thus heating the seal evenly and preventing the glass sagging in one spot). The neck moulds set at wrong height.
5.	Bad shape.	Sealing-in flames set badly. Neck moulds not set correctly and concentrically with pin tops.

9.9 COMMON PROBLEMS AND PROBABLE CAUSE - (CONTD.)

FAULTS.		PROBABLE CAUSES.
6. Cracked Seals.	Sharp seals:	a) Pins not dropping, preventing the glass from dropping between the seal heating position and neck mould position.
		b) The glass not sufficiently hot to allow it to drop.
	Bad annealing	a) Pins not dropping between the neck mould position and first annealing position.
		b) Annealing flames not set properly or annealing flames not lit.
	Neck moulds:	a) Score mark/marks in the mould (the moulds must be polished and free from any imperfections)
		b) Neck moulds not lined up correctly. Neck moulds not set at correct height.
		c) Neck moulds not heated (flames extinguished or not sufficiently hot)
		d) Too much air through pins when blowing glass into moulds.
	After cooling:	Bad adjustment of air or air pipes on intermediate turret.
	Bad cut-off:	(The cullet not completely cut off). This leaves a piece on the seal after neck moulding, which, if broken off, can cause a cracked seal.

9.9 COMMON PROBLEMS AND PROBABLE CAUSE - (CONTD.)

FAULTS.	PROBABLE CAUSES.
6. Cracked Seals - contd. -	Top of cullet splintering and glass chips sticking to seal: Burner not properly adjusted.
7. Holes in seals	Cracked/chipped flanges. Too severe heat in early stages of sealing. Burners set too high.

9.10-REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

1. Incandescent Lamps by W. G. Matheson, GTE Sylvania, Danvers, Mass.

2. Sealex Training Program
GTE Sylvania Equip. Dev. Group, Ipswich, MA 01938

3. IES Handbook from IES Society.

4. The Welding of Glass by High Frequency Electric Torch, by E. M. Guyer, Corning Glass Works, Corning, N. Y.

5. Electric Sealing of PAR 38 Lamp - Proj. 4709, GTE Sylvania - Kew Gardens, N. Y., 1953.

6. Glass Sealing by Electric Current
U. S. Patent #3,8,16,087.

7. Burner for Lamp Working by H. K. Richardson available from American Gas Furnace Co., Elizabeth, New Jersey.

8. Incandescent Sealex Practice by Raymond Conroy, GTE Sylvania, Loring Ave., Salem, Mass. 01970

STEM MAKING

10. The stem is made from the following components:

a. The flare - sometimes referred to as the flange

b. Two or more lead-in wires

c. The exhaust tube

The stem is a multi-purpose assembly. The flare seals to the bulb. The leads carry current to the filament and also physically locate the filament in the bulb. The leads are hermetically sealed to the flare. The exhaust tube is used to pump and/or fill the lamp with inert gas. The leads contain the fuse to protect the lamp against explosion, etc. The glass rod supports the moly anchors which support the filament.

Figure 10.0.1 is sketch showing the progression of materials to a complete lamp.

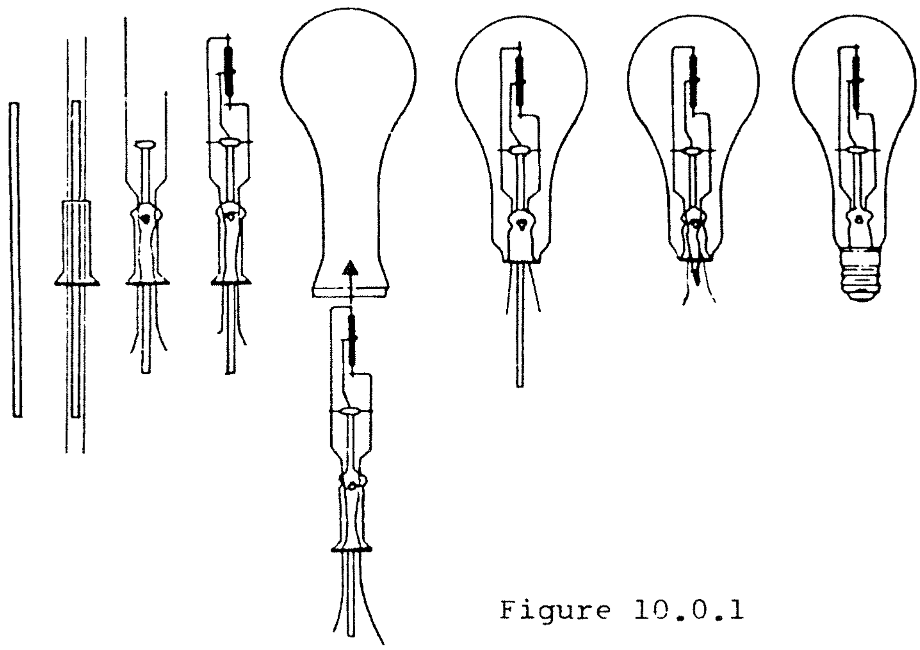


Figure 10.0.1

STANDARD DUAL

FLARE GLASS
EXHAUST TUBING
2 LEADS
SUPPORT WIRE
FILAMENT

AUTOMOUNT

2 LEADS HERMETICALLY SEALED IN GLASS
FILAMENT MOUNTED & SUPPORTED

BULB SMOKED

SEALING TURRET

BULB & MOUNT ASSEMBLED

EXHAUST TURRET

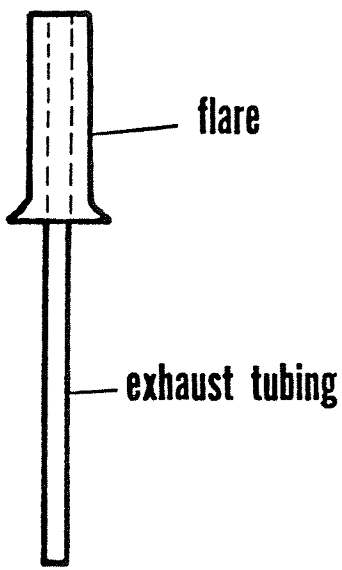
LAMP PURIFIED
LAMP TIPPED

PRE-FILLED BASE

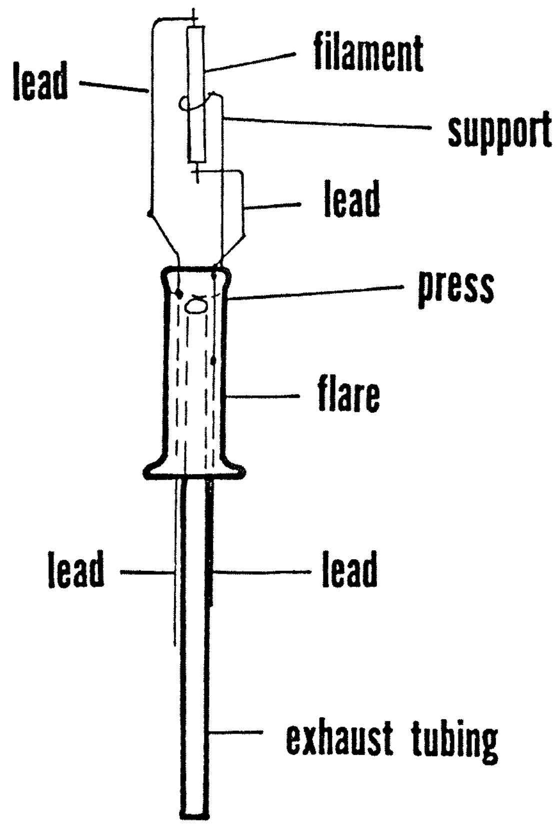
FINISHING MACHINE

LAMP THREADED
CEMENT BAKED
WIRES WELDED & SOLDERED
FILAMENT FLASHED

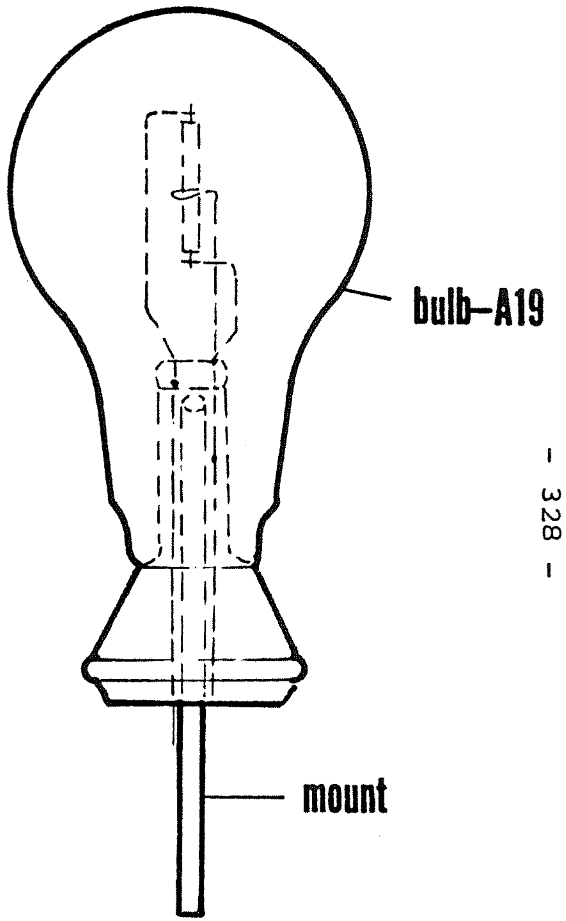
STANDARD DUAL LAMP



FLARE & EXHAUST TUBING

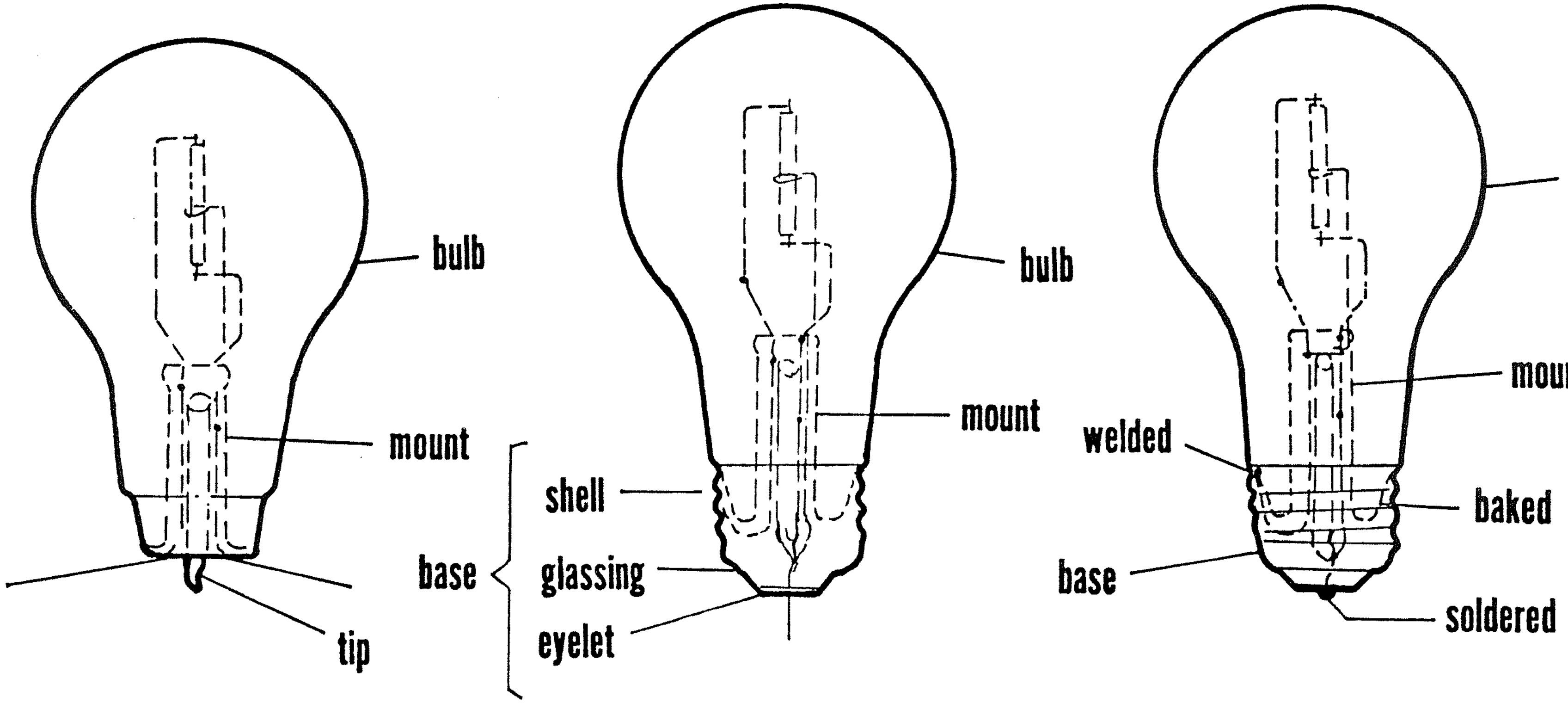


MOUNT



SEALED LAMP

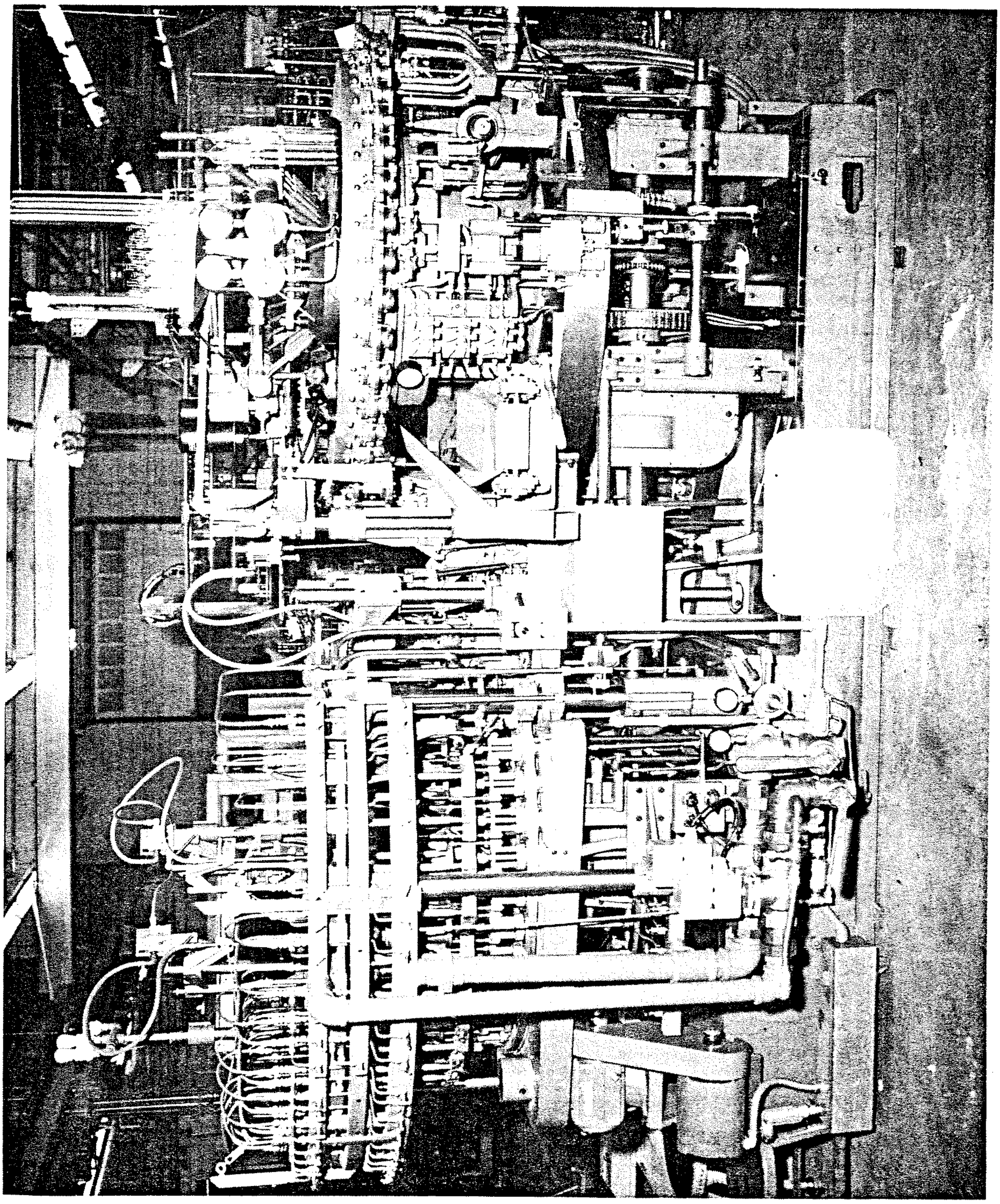
STANDARD DUAL LAMP



WIRE LAMP

BASE & LAMP ASSEMBLY

FINISHED LAMP



SEALEX MACHINE

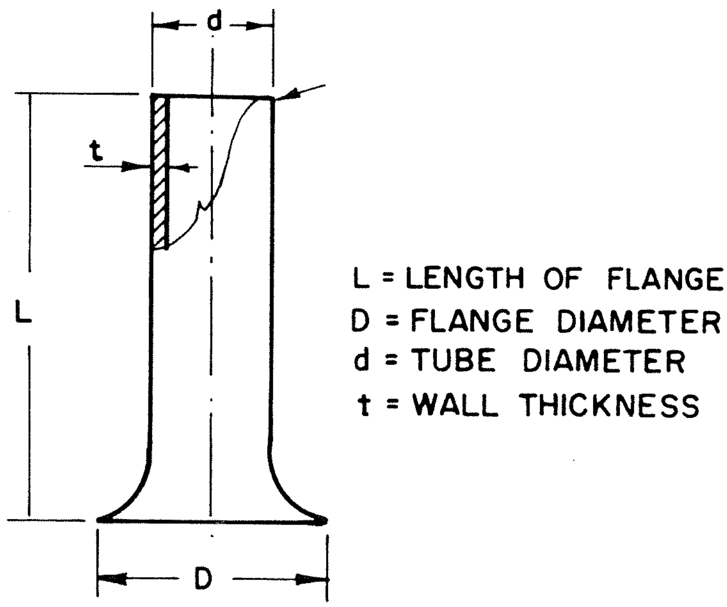
STEM MAKING

The flange is the foundation component on which the lamp is built. Any fault in this component can cause faults in subsequent operations of lamp making, resulting in rejects.

All glass used in normal incandescent lamps is 'soft' glass. There are two types of soft glass used - "LEAD" glass (softening point 630°C) and "LIME-SODA" glass (softening point 710°C).

At the speed of production required, Lead glass is used for flanges due to a lower softening point than Lime-soda glass.

Figure 10.0.2 is a drawing of a typical flange.



FLANGE

Figure 10.0.2

10.1 FLARE MAKING

There are three standard types of equipment for making flares.

1. The vertical hot cut flare machine
2. The horizontal Swansen Erie Flare Machine
3. The Sylvania score and shock glass cutter and automatic spin out flaring machine

10.2 The Hot Cut Flare Machine

The hot cut flare machine produces flares by the following general cycle:

1. A stick of glass tubing is held vertically in a chuck.
2. The chuck is released and the glass tubing is allowed to drop down to a fixed stop.
3. Fires heat the lower end of the glass tube - head is rotating at about 50 rpm.
4. A reamer comes up and pushes the softened end of the tube in such a way that the tubing is flared out.
5. The reamer retracts and fires are played on the tubing some distance above the flare.
6. A small diameter cutter comes up inside the tubing and stops at the heated area and then moves away from the center toward the tubing wall. At the same time, a larger diameter cutter is located outside the tubing and

10.2 THE HOT CUT FLARE MACHINE - (CONTD.)

6. moving toward the same point on the tubing as the inside cutter. The result is a shearing-cutting action which cuts the completed flare and prepares the tubing for the next cycle. The completed flare is then fire polished and annealed.

Figure 10.2.0.1 is sketch of the flaring tool or flange reamer.

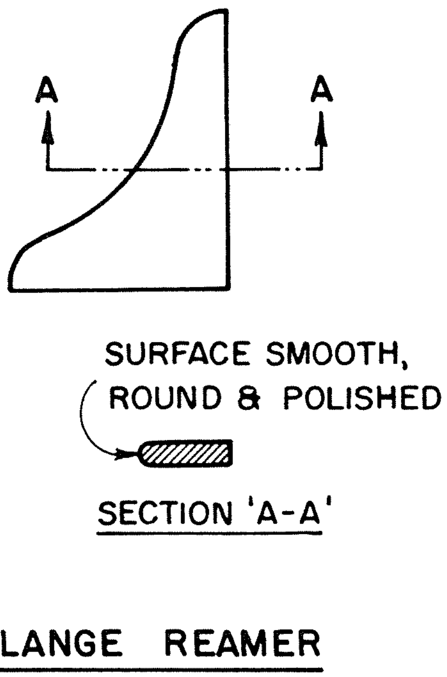


Figure 10.2.0.1

10.2.1 KEY POINTS FOR MACHINE SETUP.

The key points to control on the machine are:

1. For good cutting off:
    a. Accurate setting of the inner cutting knife in relation to the outer cutting knife.
    b. The sharpness and diameter of the knives.
    c. The setting of the flames exactly in line with the cutting knives. See Figure 10.2.1.1.
2. For good flanging:
    a. Correct setting of the burners to give a good melt. Some SO_2 is added to combustion gas for a glass lubricant.
    b. The flanging reamer must be smooth and kept polished and free from grooves or marks.

       Flanges made from glass 11-13 mm diameter with a flange diameter 19-22 mm are better reamed with a fixed reamer.

       Using this type and shaped reamer it is possible to maintain a smooth radius from the flanged end to the tubing. See Figure 10.2.0.1.

       Note: When working glass, in order to minimize strain, the finish must always be radiussed.

       The larger the radius the better.

       Strain in glass is dealt with as a separate subject.

       For factory control, strain is observed by viewing the component under POLARISED LIGHT. The apparatus is called "STRAIN VIEWER".

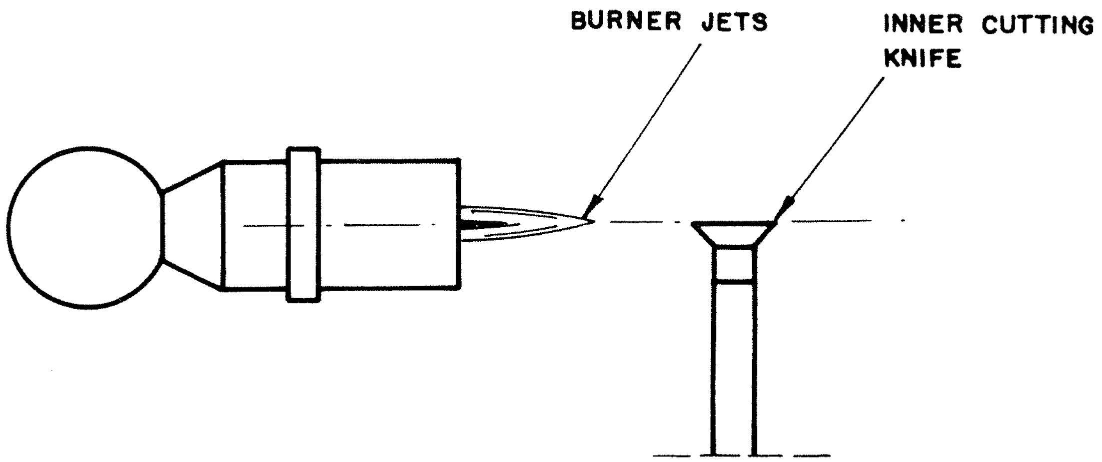
10.2.1 KEY POINTS FOR MACHINE SETUP - (CONTD.)

3. End glazing is important. The cut ends of the flanges are glazed with flames in order to seal minute cracks, thus giving polished ends. This ensures the avoidance of cracks and chips during handling and subsequent operation.

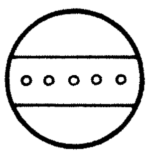
4. The flanges must be inspected on a glass plate, illuminated by Sodium lamps. The monochromatic light source from a Sodium lamp enables the inspector to see any cracks or defects in the glass very easily.

5. Physical dimension gauges are supplied. They are fixed on the inspection bench for quickness of operation. Inspection at random (including 'Strain' viewing) is carried out by the quality inspector.

FLANGING MACHINE



JETS OF BURNER MUST BE HORIZONTAL



FACE OF BURNER

WHEN HEATING THE GLASS TUBE PRIOR TO CUTTING OFF, ONLY A NARROW BAND MUST BE HEATED.
THE BAND TO BE HEATED MUST COINCIDE EXACTLY WITH THE CUTTING KNIVES. IT IS ESSENTIAL THAT THE BURNERS ARE SET TO ACHIEVE THIS.

Figure 10.2.1.1

10.2.2 COMMON FAULTS AND CAUSES OF PROBLEMS ON HOT CUT FLARE MACHINES

1.	Chipped Flanges	Bad flame annealing. Bad handling.
2.	Wavy Flanges	Glass too hot when reaming. Annealing flames too hot.
3.	Wrong Dimensions	Wrong machine setting.
4.	Reamer/score marks	Reaming with glass too cold. Bad Reaming tool.
5.	Bar Ends	Cutting knives not sharp. Cutting knives badly adjusted. Flames not adjusted properly.
6.	Bad end glazing	Flames not adjusted properly.

10.3 Sylvania Cut and Spin Flare Machine

The general machine cycle is as follows:

1. A separate machine cuts tubing in correct length flare blanks. The machine is a multi-cut unit that makes 4 cuts in each cycle. The cut is made by heating a narrow band and then scoring the glass with a sharp carbide knife. The cut tubing drops onto a turret which moves the cut end through pre-polishing fires. The other cut end is fire polished before it is indexed for the next cut. The cut and fire polished pieces are collected in boxes.

10.3 SYLVANIA CUT AND SPIN FLARE MACHINE - (CONTD.)

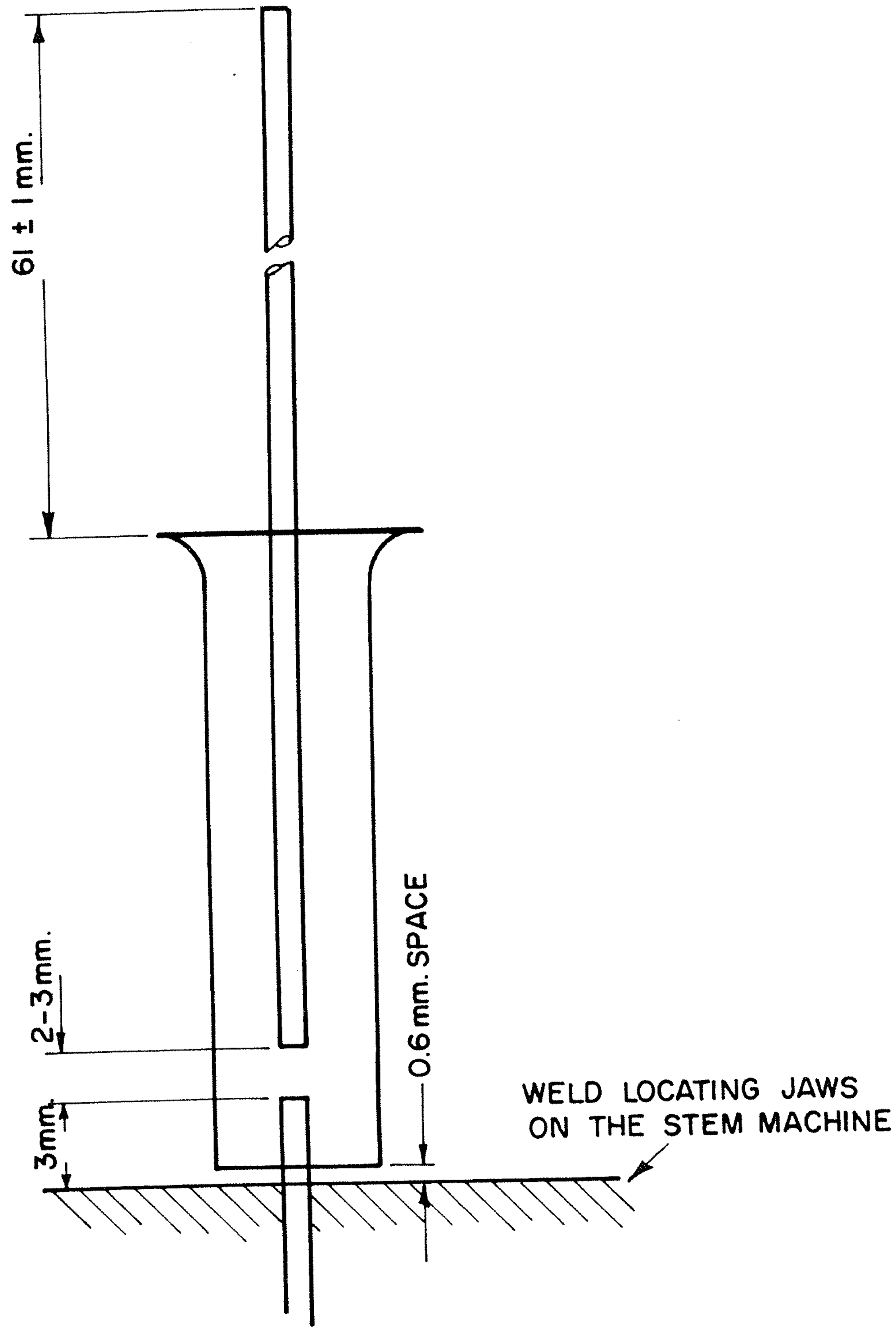
2. The flare machine has 4 flaring positions and acts like 4 separate machines. The boxes of cut tubing are dumped into 4 Syntron bowls. The glass is fed from these bowls and loaded vertically on head pins. The pins and glass rotate and the top open end of the glass is heated. When glass is soft enough the tube end is expanded by centrifical force and spins the glass out to make a flare. The shape of the flare is controlled by the heat pattern. The completed flares are annealed on a belt furnace.

Figure 10.3.0.1 is a view of the glass cutter.
Figure 10.3.0.2 is a view of the four-position Sylvania flaring machine.

10.3.1 COMMON FAULTS AND CAUSES OF PROBLEMS ON SYLVANIA CUT AND SPIN FLARE MACHINES

Figures 1 through 6 show some problems, causes and remedy of some common defects.

STEM MAKING



IMPORTANT SETTING-UP DIMENSIONS
FOR STEM MACHINE

Figure 10.8.0.1

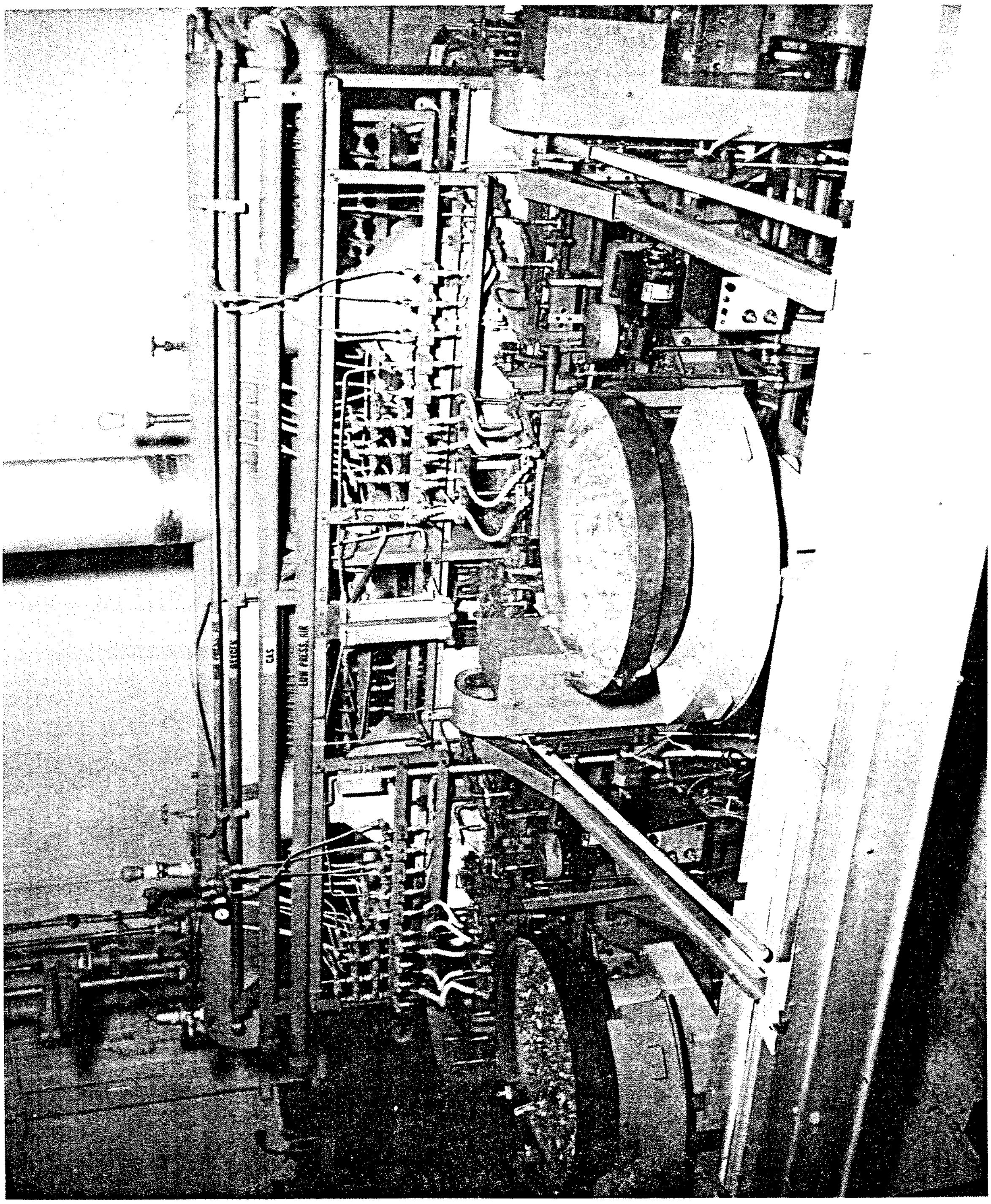


Figure 10.3.0.2

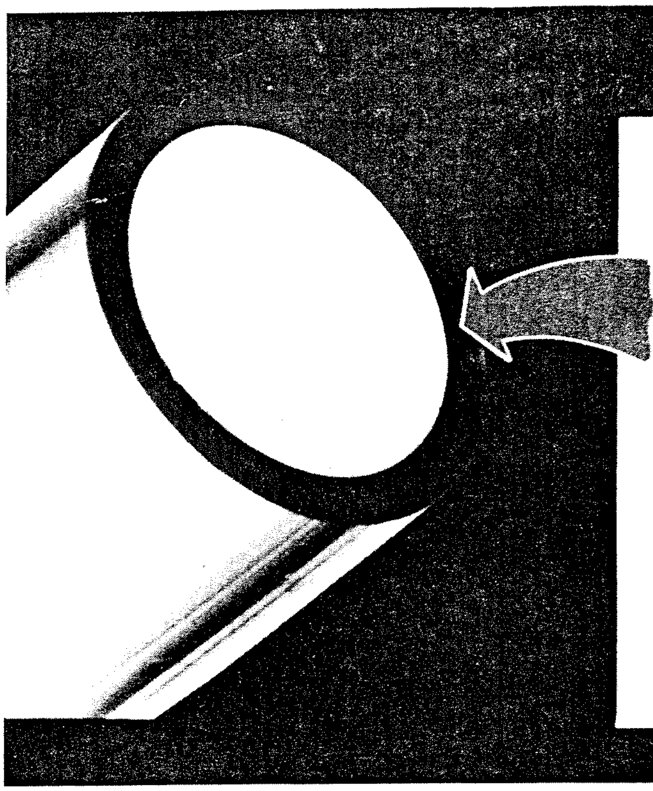


FIG. 1

No Defect
Smooth, square ends.

Note: Cutting blade and fire adjustments are correct ---- don't change !!!

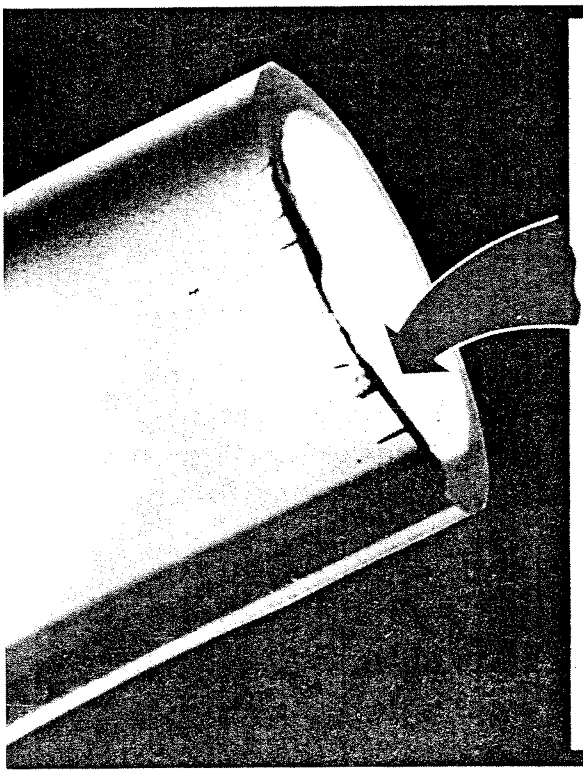


FIG. 2

Defect:
Part of surface is rough and cracked.

Cause:
Cutting fire is a little too hot.

Remedy:
Reduce heat – see instruction manual.

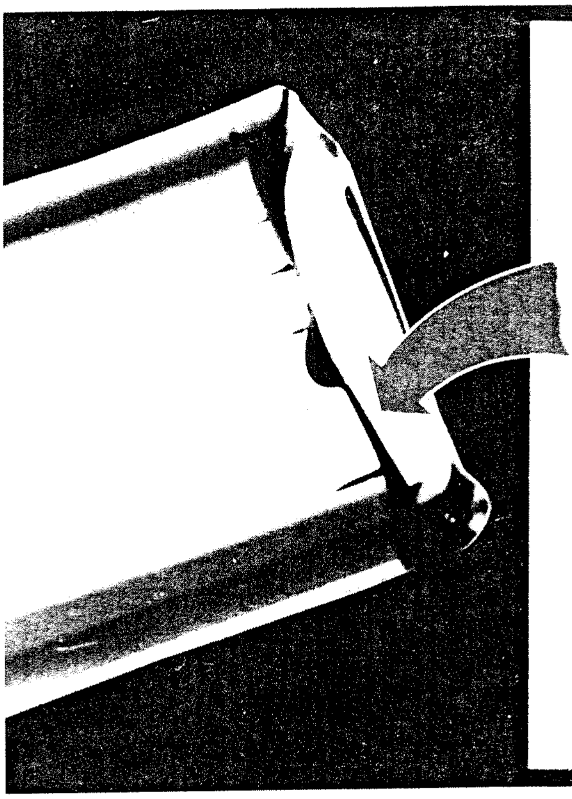


FIG. 3

Defect:
Most all of end surface is rough and cracked.

Cause
Cutting fire is much too hot.

Remedy
Reduce heat — see instruction manual.

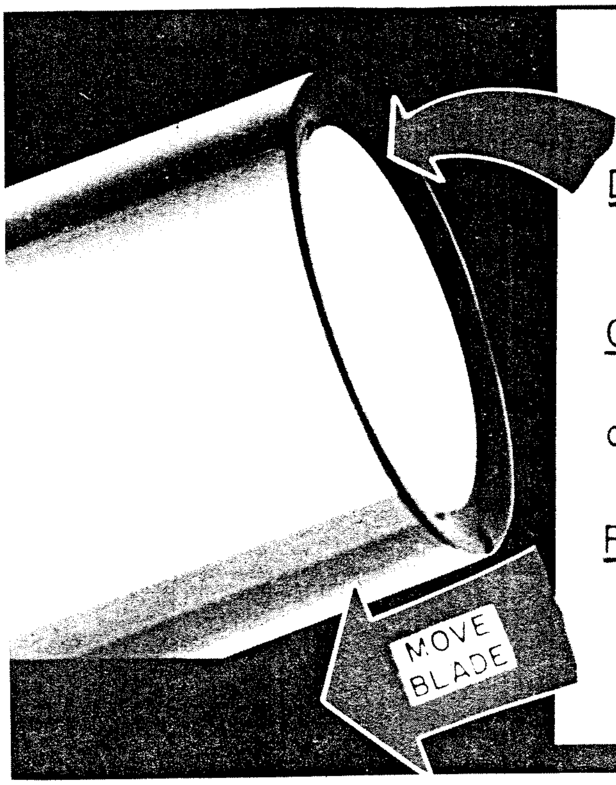


FIG. 4

Defect:
Concave end.

Cause:
Cutting blade is out of position.

Remedy
Move blade in direction of arrow. See manual.

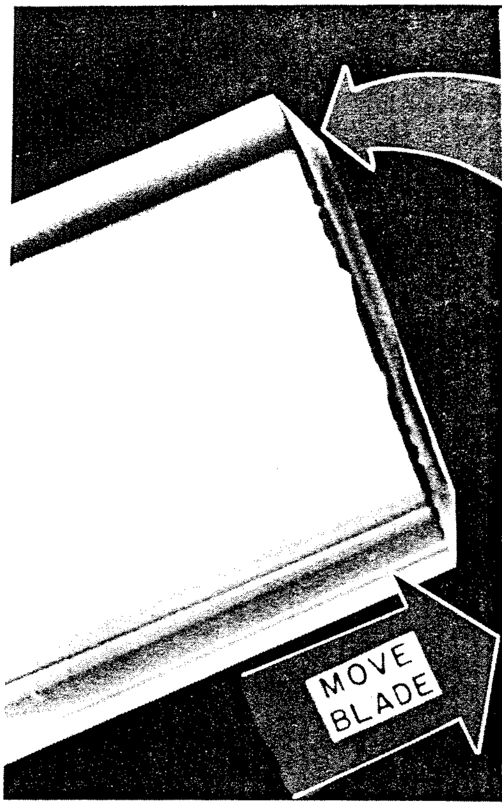


FIG. 5

Defect:
Convex end.

Cause:
Cutting blade is out of position.

Remedy
Move blade in direction of arrow. See manual.

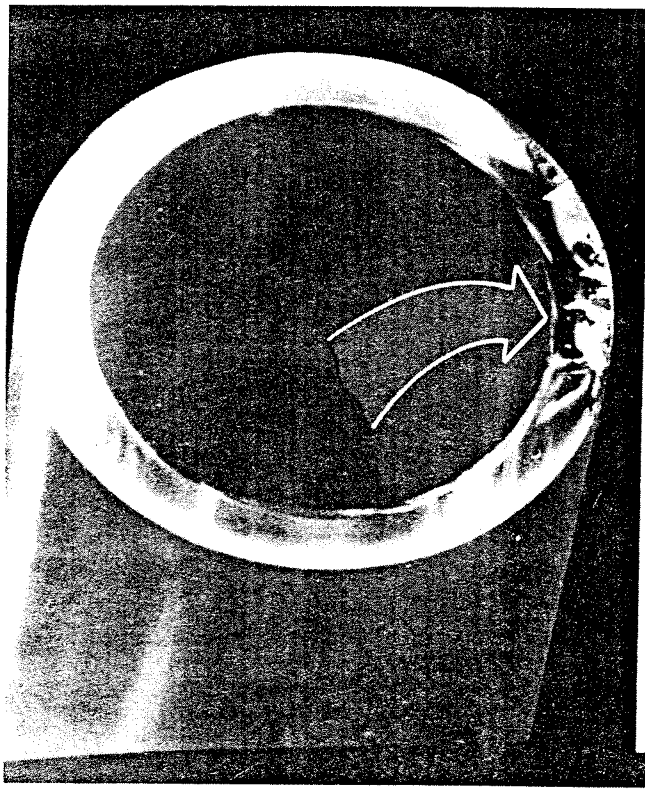


FIG. 6

Defect:
Crushed area in small section of end.

Cause:
Cutting blade hitting glass too hard.

Remedy
Reduce pressure. See manual.

10.4 THE HORIZONTAL SWANSEN ERIE FLARE MACHINE

The Horizontal flare machine is similar to the hot cut vertical flare machine in the actual flaring operation. The tubing cut-off operation is different. The cut-off is accomplished by a scoring on the outside of the tubing followed by heating on the inside of the tube by a sharp pin point flame. To accomplish this a thin tube with a hole perpendicular to the tube is inserted into the flare tubing so that the hole in the burner tube is exactly opposite the score on the outside of the tube. In operating, the hole becomes the burner orfice for the pin point flame.

The advantage of the Swansen Erie Horizontal Flare Machine is that it is automatically loaded with the long glass sticks whereas vertical equipment must be reloaded by hand for each new stick of glass. The horizontal equipment is faster but the set up for good flares is more critical than the hot cut equipment.

10.5 FLARE SIZES

Bell diameter is determined by the base which is to be used on the finished lamp. Normal flare diameters are as follows:

9½ mm.	-	Candelabra
11½ mm.	-	Double contact and intermediate
14 mm.	-	S11 medium
20 - 21½ mm.	-	All regular medium
25½ mm.	-	All regular mogul
31 mm.	-	PS52 and larger mogul

Light center length required and individual mount machine limitations determine the overall length of the flare which is used. Flare lengths vary from 16½ mm. up to 85 mm.

10.6 Exhaust Tubing

Exhaust tubing is also made from lead glass, which is purchased in pre-cut lengths.

On small type lamps, such as S6 and C7, a relatively small exhaust tube diameter is used because there is no need for a large passage to evacuate the lamp. The weight of the finished lamp can easily be supported by the smaller exhaust tubing.

Larger type lamps such as PS40 and PS52, require a much larger tubing because an increased amount of gases must be evacuated and lamp weight has greatly increased.

10.7 Lead Wires

Lead wires are made up from three separate pieces of wire welded together. The inner section, which is inside the finished

10.7 LEAD WIRES - (CONTD.)

lamp is either nickel or a copper nickel plate in gas-filled lamps. For vacuum lamps a copper or dumet wire is used.

Copper tends to oxide readily. In gas-filled lamps, slight traces of hydrogen which might be present would reduce the oxide and form water which would cause early blackening and short life. Since nickel or nickel-plated copper do not oxidize as readily, they are used for gas-filled lamps. In vacuum lamps there is no hydrogen present, so copper leads are satisfactory.

The red portion (center section) of the lead is the dumet. This is the section, which is sealed to the glass, in the press of the stem. Dumet has a center core of nickel-iron alloy with an outer coating of copper oxide. This combination is used to give the lead wire a similar coefficient of expansion to the glass in the press.

The outer section of the lead can be copper, copper nickel plate or nickel. There are many factors which determine the type and size of the material which is to be used. Some of these factors are:

1. In a vacuum where there is no requirement for a fuse wire, copper is used for both wires.
2. In a gas lamp where a fuse wire is required, the fuse is either nickel or a copper nickel plate of small diameter. A fuse is used on one wire, the other can be either copper or nickel, once again depending upon application.

See Chapter Lead Wires and Fuses.

10.8 STEM MANUFACTURING

There are many types of stem machines but they all perform common manufacturing steps.

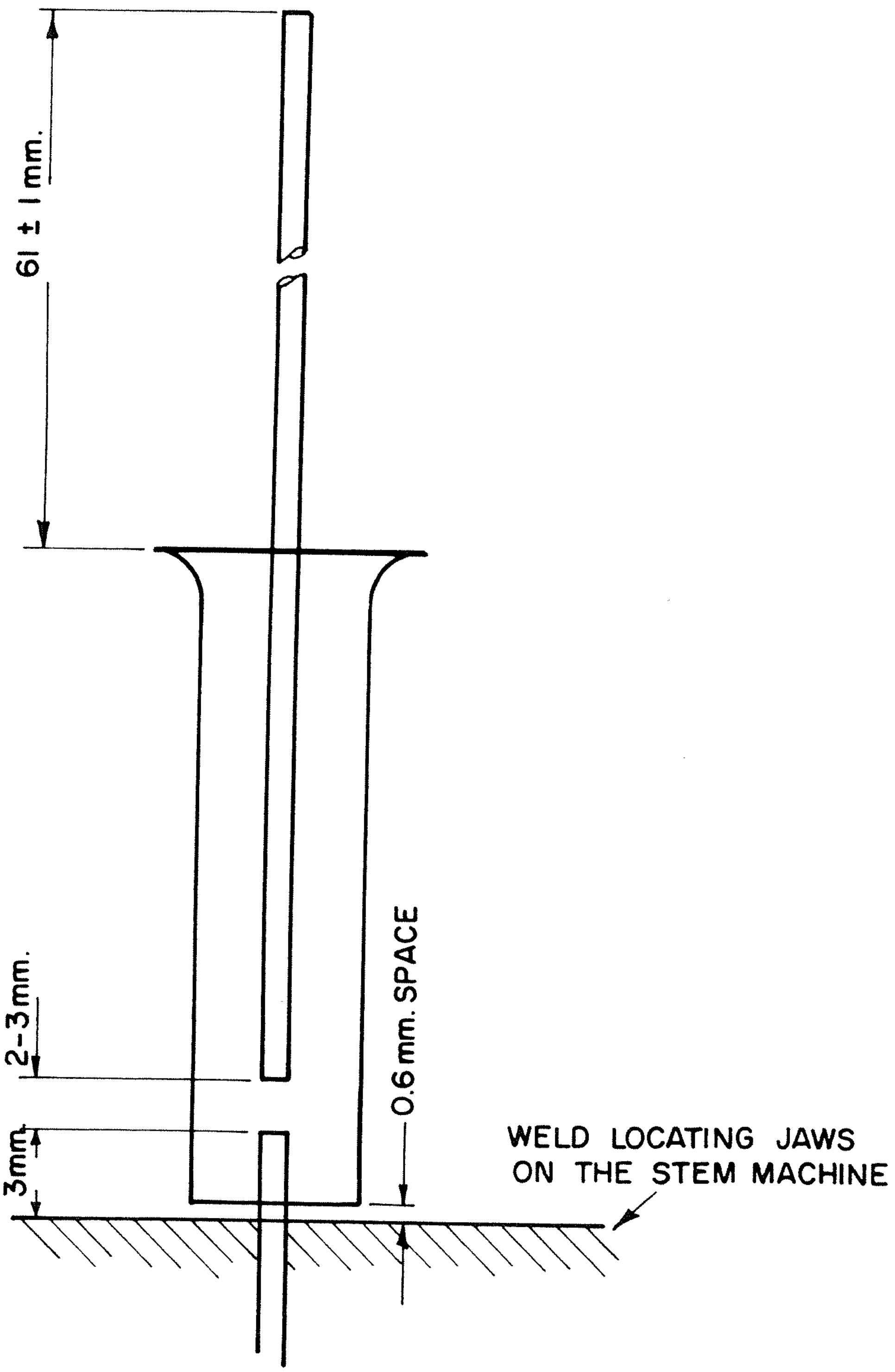
The components are fed automatically and individually - flange, leading-in wires, exhaust tube. The machine is fitted with 'no feed' trips so that a failure to feed a component will prevent feeding of subsequent components. For example, if a flange fails to feed, the subsequent components - leading-in wires and exhaust tube will not feed.

The first component to be fed is the flange tube. The flange tubes are contained as a random pile in a vibrator unit. At the top of the vibrator track they are released on to slide rails. A gate mechanism allows one flange tube to be fed into the flange jaws of the head.

The leading-in wires are fed into containers. The lead-in wire is picked out of the bundle with the mechanical tweezers and dropped into the weld block. The tweezers have two grooves, so designed that two chances are given for pick up. The size of the groove allows for only one wire to be picked up at a time. The weld blocks (sometimes referred to as wire pots) are flanged out at the top for easy feeding of the wires.

The exhaust tube is fed automatically. The tubes are contained in a hopper and are released one at a time via a gate mechanism. The stem machine heads are fitted with wire-locating jaws, which, when closed, position accurately the lead-in wires.

STEM MAKING



IMPORTANT SETTING-UP DIMENSIONS FOR STEM MACHINE

Figure 10.8.0.1

10.8 STEM MANUFACTURING - (CONTD.)

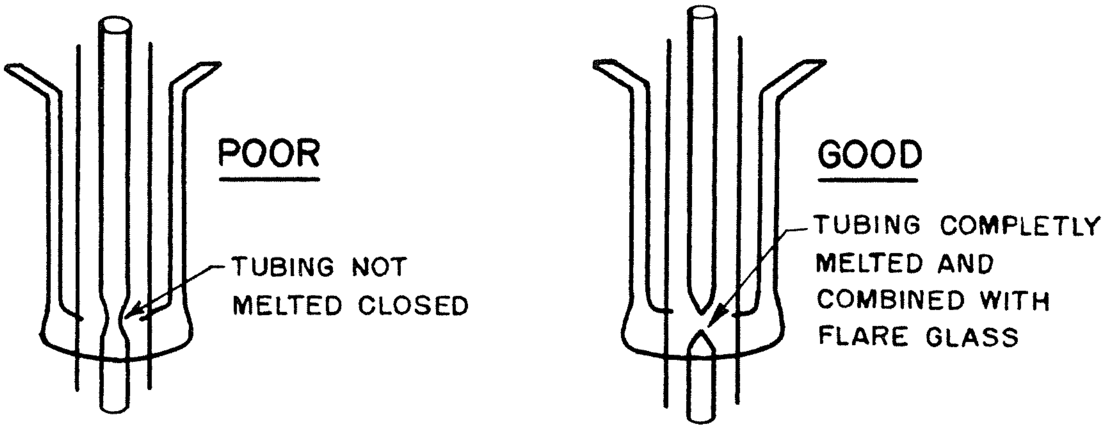
After the exhaust tube has been fed, it is pushed down to the correct length. At the same time the rod is pushed up to the correct length. The flange is pushed down. A spacer comes between the end of the flange and the closed wire locating jaws, so that there is a space of 0.6 mm. If the flange were pushed down on to the jaws, subsequent melting would be difficult as the metal of the jaws would take away heat rapidly. This space allows the glass to fold in at the bottom.

The relative positions of the component parts are illustrated on Figure 10.8.0.1.

At this point the materials are in the proper position to be sealed into one unit.

The first fire positions are used to slowly heat the end of the flare so that it will not fracture. A soft fluffy fire, with no oxygen, is used in at least the first fire position. From pre-heat to the first press, the flare glass and exhaust tubing are heated to a molten state. The exhaust tube should completely melt closed, as illustrated below, just prior to the first press to insure a good seal.

10.8 STEM MANUFACTURING - (CONTD.)



The first press is used to force the glass around the lead wires, insure the closing of the tube and shape the press.

There are three processes which take place between the first and second presses; shoulder forming, blow hole forming, and completing the seal to the lead wires.

Figure 10.8.0.2 shows the general progression of the glass forming.

10.8.1 Sealing Lead to the Glass

Located between the first and second presses are from four to five burner positions. At least two of these stations use oxygen fired burners for added heat capabilities. These burners are adjusted so that the red dumet color changes to straw color on a cool stem. The change in color of the dumet is the result of the copper oxide combining with the glass, in the immediate area of the lead wire.

STEM MAKING

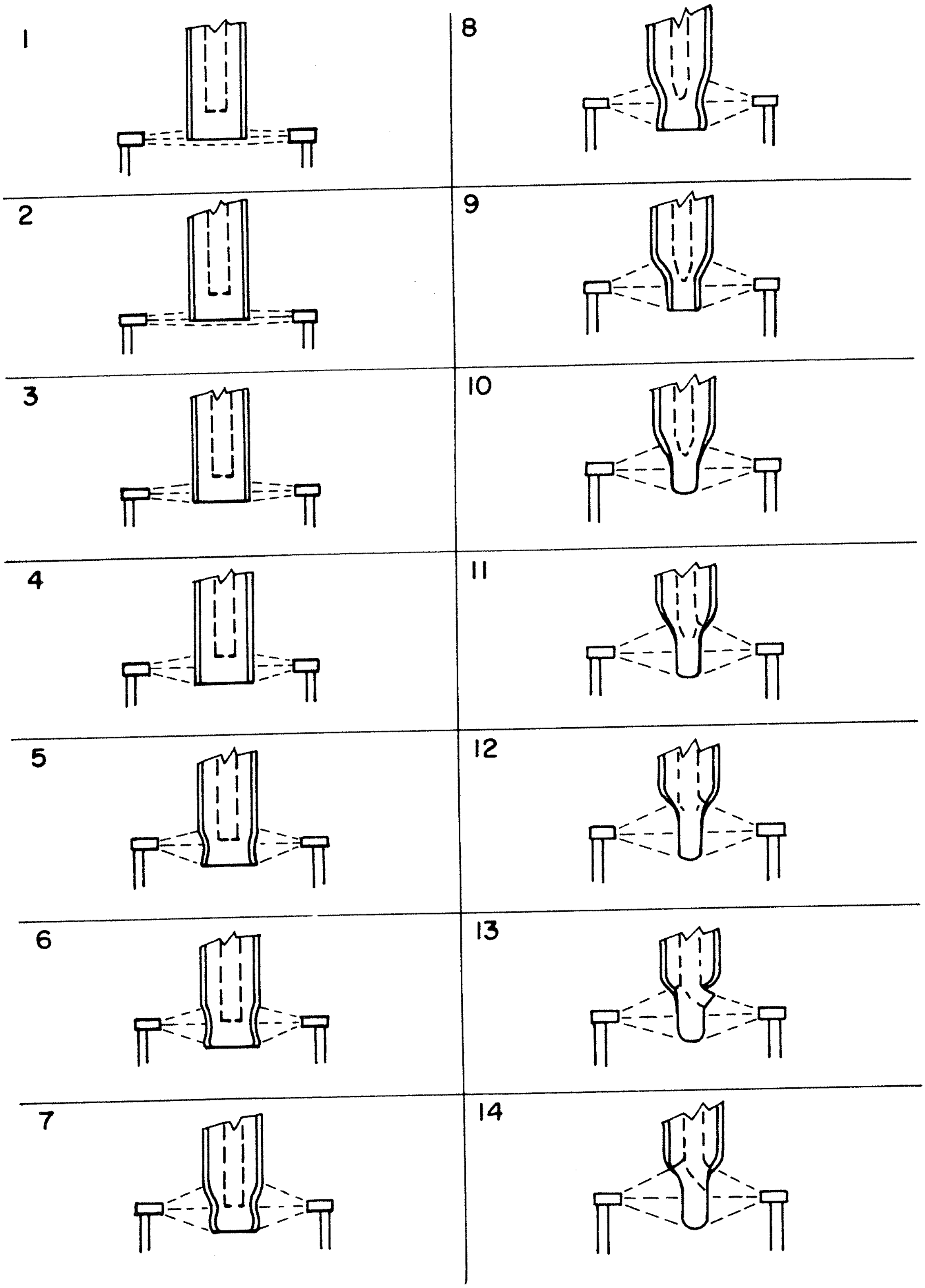
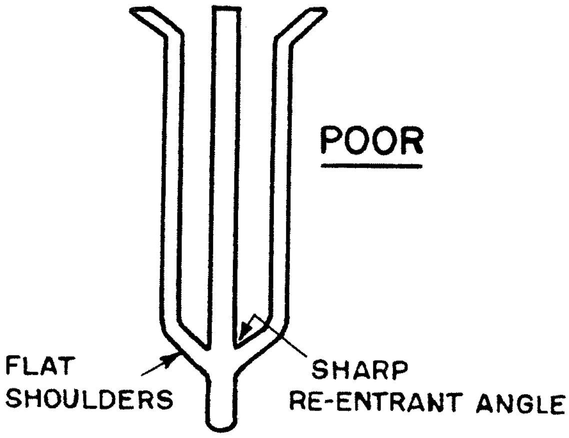


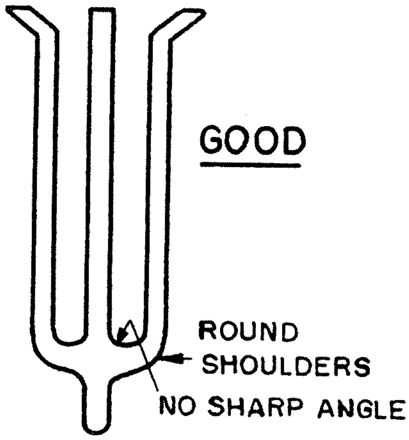
Figure 10.8.0.2

10.8.2 SHOULDER FORMING

Shoulder forming is accomplished by blowing heated air, through an air jet, into the open end of the flare. Heated air is used so that the glass will not be cooled during the shaping process.

Examples below illustrate poorly and good shaped shoulders.





10.8.3 Blow Hole Forming

Heated air is also used in forming the blow hole, similar to shoulder forming. The air in this case is directed into the upper end of the exhaust tube. Two stations are used, the first has only enough air pressure to start forming the blow hole cavity and bubble out a small amount of glass. The second station completes the hole, but with only enough air pressure to open the blow hole cavity.

10.8.4 Final Press and Blow Hole Glazing

Two operations are performed in the final press station. First, the press is formed or slotted so that a heat deflector

10.8.4 FINAL PRESS AND BLOW HOLE GLAZING - (CONTD.)

can be inserted on the finished stem. A coded date number is also applied during this forming operation. Second, the blow hole is glazed or burned back flush with the surrounding glass on the press.

10.8.5 Cooling and Annealing

Cooling air is then directed both inside the flare and on the outside surface of the press, in the stations between the final press and the annealer. The amount of air used is dependent on the distance the stem must travel and the elapsed time before it reaches the annealer. Air is used both inside and outside so as to cool the entire press area at the same rate. Cooling is adjusted so that the stem press is at 440^{o}C as it enters the first annealing station.

The burners in the annealer are run with no oxygen and a soft fluffy fire. The purpose of the annealer is to allow the stem to cool slowly through the strain region (440^{o} - 390^{o}C) to prevent high stresses.

A stem which has been properly annealed viewed in a polariscope would have a light blue color around each lead wire. This blue should taper off to an orange-red toward the center of the press, with no sharp color contrasts.

10.8.6 Burner Settings

a) The burners must be set so that the flames are 5-6 mm from the top of the weld locating jaws. The flames from each pair of burners must be even. Burners with

10.8.6 BURNER SETTINGS - (CONTD.)

a) blocked jets must be cleared.

b) The burners must be set at the same height and positioned so that the glass flanges are in the centre of the flames.

c) The first burners must be set so that the glass is warmed up gently. Fierce flames suddenly on cold glass will crack it.

d) Gentle heat must be applied for 2 or 3 positions and until the bottom of the flange tube melts in and shields the lead-in wires. The flange tube is pushed down initially on to a withdrawable platform about 0.6 mm thick so that the bottom of the flange tube is just clear of the weld locating jaws. This makes it possible for the glass to melt up and close in. THIS IS VERY IMPORTANT.

e) The heat is increased in subsequent positions to melt together the glass components (exhaust tube, flange and rod) and to fuse the glass around the leading-in wires. THE HEAT MUST NOT BE SO INTENSE AS TO BURN THE LEAD-IN WIRES.

f) The glass is Lead Glass and the air-gas ratio to the burners is important. Too much gas will cause the glass to blacken (Black Pinches).

g) After the glass components have been melted into one homogenous mass they are pinched. After pinching, the junction of the exhaust tube in the pinch should show as a point. If it shows as a semi-circle or 'half moon'

10.8.6 BURNER SETTINGS - (CONTD.)

g) this is an indication that the glass is not sufficiently hot or that the burners are set too low.

h) After pinching the stem is heated prior to the hole blowing position.

i) At the hole blowing position, compressed air is blown down the exhaust stem to blow the hole and down the flange to blow out the well (above the pinch). Excess air on hole blowing will chill the glass, causing 'weak stems'. Excess air on well blowing will blow a hole in the side of the flange tube.

j) In the position following the hole blowing the burners are set to glaze back the rough edges of the exhaust hole. Excess heat or burners set too high will distort the rounded shoulder of the well above the pinch and weaken the joint (flange-exhaust tube). In the same position the press feet on this second pinch mechanism are 2 mm narrower than on the first pinch mechanism and must be set ½ mm farther apart to avoid too much disturbance of the glass, which could cause strain in the glass, possibly resulting in 'cracked pinches'.

k) After the last press and blow hole glazing, the stem glass work is complete. The stem is cooled down gradually and either removed to a stem annealer or continues on to mounting as on a Sylvania automount.

10.8.6 BURNER SETTINGS - (CONTD.)

Figure 10.8.6.1 shows a general review of a typical Sylvania Automount

10.8.7 Inspection of Stem Manufacturing Process

Note: Defects in stem manufacture often are not revealed until stems are reheated at the sealing-in operation. Therefore, the stem making process must be carefully maintained and monitored.

CHECK AND INSPECT:

1. No glass cracks.
2. Alignment, stem-flange.
3. Dimensions.
4. No burnt wires in pinch.
5. No leaky pinch (glass not completely fused to leading-in wires. See Figure 10.8.7.1.
6. Copper clad wires in pinch correct colour. Red wires in pinch indicate weak bond between glass and wire (Copper oxide not sufficiently dissolved into glass caused by insufficient heat when melting). Colour must be 'straw' colour to light red.
7. The well or shoulder of the flange blown to good shape.
8. The exhaust tube at junction blown out (this gives mechanical strength).
9. The lead-in wires in centre of pinch.
10. The lead-in wires well anchored in the pinch.
11. Hole in pinch.

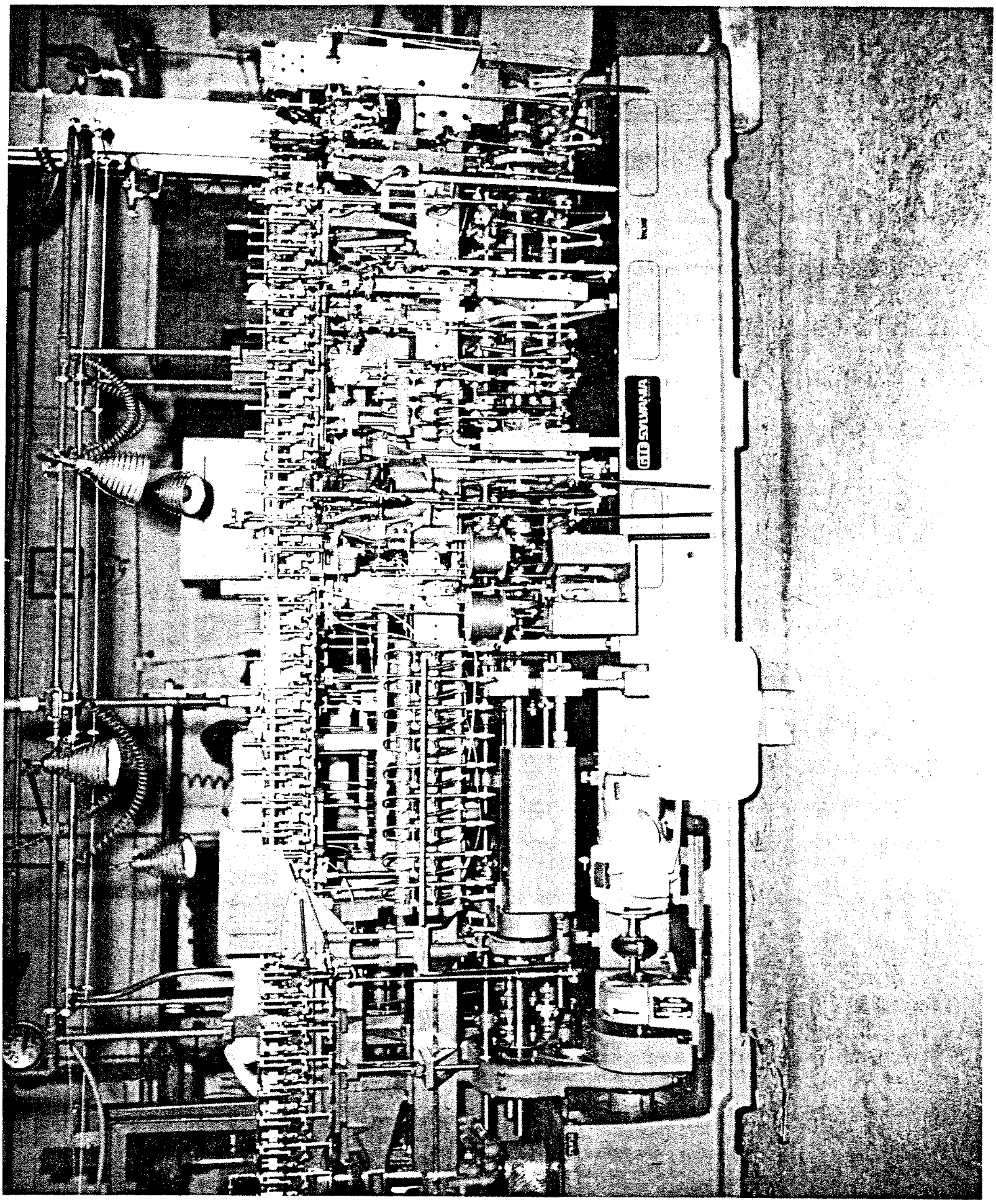
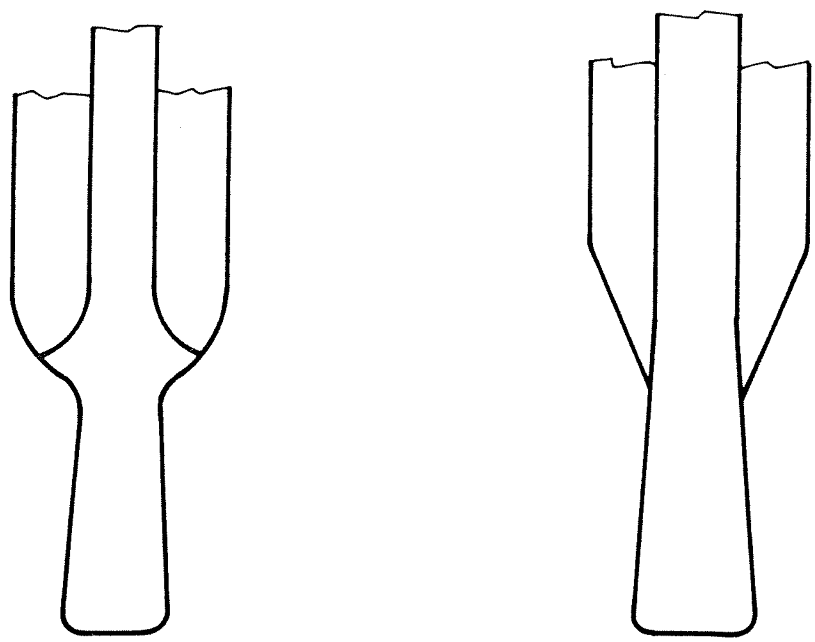


Figure 10.8.6.1

FAULTS IN STEM MAKING

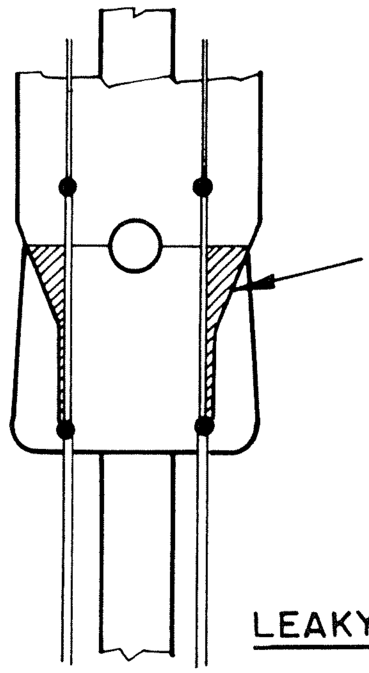


CORRECT

FLANGE TUBE WELL BLOWN OUT, BASE OF EXHAUST WELL FLANGED OUT.

INCORRECT

FLANGE TUBE NOT BLOWN OUT, BASE OF EXHAUST NOT FLANGED OUT.



GLASS HAS NOT FUSED TO THE WIRES "COLD PINCHING"

LEAKY PINCH

Figure 10.8.7.1

STEM MAKING

FIGURE 10.8.7.2 shows a typical complete well made stem for GLS Lamps.

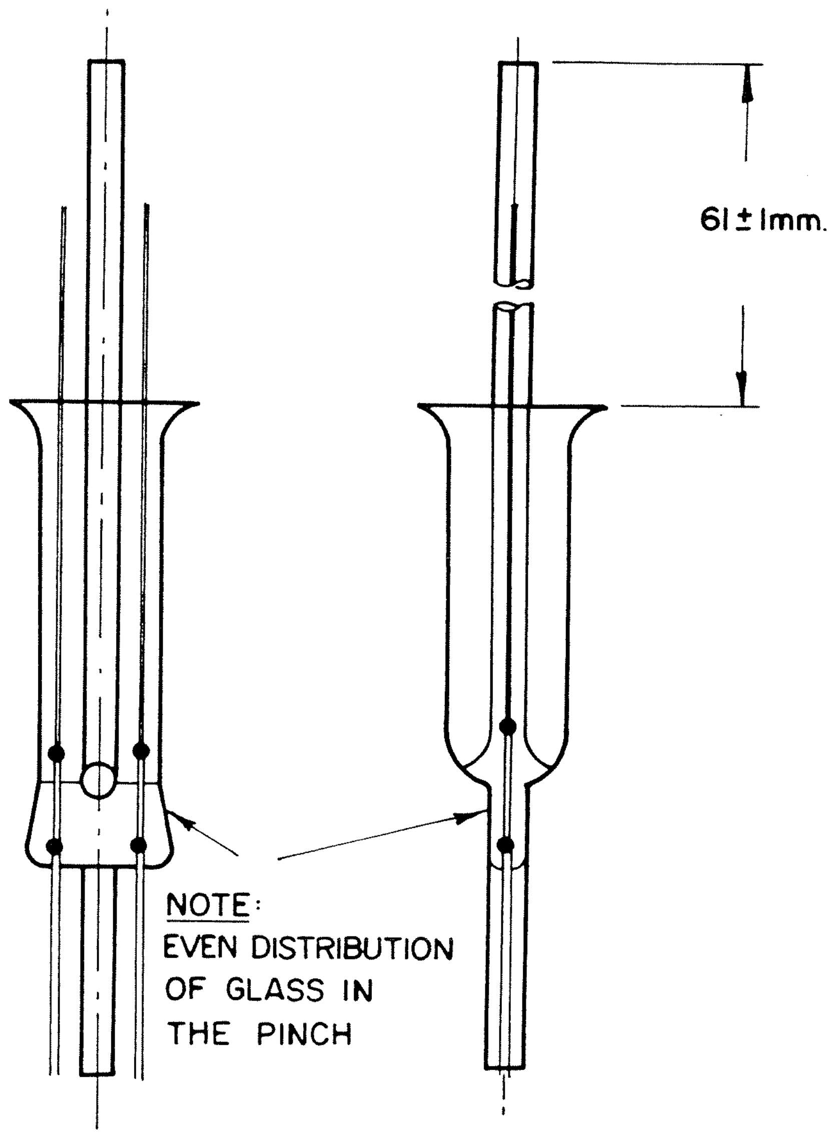


FIGURE 10.8.7.2

10.8.8 Common Problems - Causes and Cures

1.	Chipped flanges at ends when melting.	First flames too hot. Flanges not properly end glazed.
2.	Exhaust stems out of line.	Heads of machine require lining-up. Exhaust stems not sufficiently cool when transferring into Annealer causing stems to be bent by extractor.
3.	Wrong dimensions	Wrong components. Wrong machine setting.
4.	Weak exhaust stems	Bad annealing. Stems not blown out at junction to pinch.
5.	Leaky pinches	Insufficient heat. Glass not flowing around and joining to the copper clad wires.
6.	Burnt copper clad in pinch.	Weld locating jaws burnt away. Flames set too low so that they creep under the flanges.
7.	"Cold Pinches"	Too little heat. "Cold Pinches" are often caused by the end of the flanges being pushed down so that they rest on the weld locating jaws. Check the position where the flanges are pushed down to see that the

10.8.8 Common Problems - Causes and Cures

7. "Cold Pinches" (Contd.)	spacing strip is operating effectively.
8. Cracked Pinches	Incorrect annealing. Glass not blown out just above pinch. Removing stems from the annealer before they have passed through the annealing cycle.
9. No hole in Pinch.	Head or heads not lined up so that the exhaust tube misses the hole blowing tube. Glass not hot enough. Flames at hole blowing position extinguished.
10. Air Bubble in seal	Soiled or oxidized copper clad (dumet) wire. Poorly adjusted burner causing slight burning of the leads before being surrounded by the glass.
11. Red wires in Pinch	Copper oxide not dissolved into glass - insufficient heat.
12. Pinch not in center of stem	If fault is on all stems, pinch hammer mechanism should be adjusted. If fault is on individual stems, heads should be adjusted.

10.8.8 COMMON PROBLEMS - CAUSES AND CURES - (CONTD.)

13.	Exhaust Stem. Flange tube and rod out of alignment.	Heads require lining-up.
14.	Too much strain in glass.	Bad annealing.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT

It is a good practice before making mounts for production to run through a half dozen flares and follow them around the machine making sure that all fires are lit and observing presses and blowers to see if they are functioning properly. This will involve checking the shape of the stem and the flow-meter settings as well as the yoke fire and air jets.

AUTOMOUNT

Items Affecting Cracked Flares

1. Syntron Feed and Hopper
   - A. Handling of Flares - It is most important to handle the flares as gentle as possible. Do not throw them roughly into the hopper. The more broken glass there is, the more likelihood of scratching the flares resulting in cracked flares later at sealing.
   - B. Syntron Bowl - Minimize the fall of the flares down the chute by slowing up with asbestos flaps. Place a rubber pad at the bottom of the chute. (Scotch-Tred used now on bowl runs, etc.) Tests show 100% good flares dumped into hopper will show up 1. to 2.% breakage.)

2. Flare Transfer
   - A. Make sure flare clears stationary and movable jaw (opened wide enough) and that the flare is centered to give clearance on each side.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

2. B. Make sure flare transfer arm stroke is positioned so that flare will not be carried too far and hit back of movable jaw.

3. Flare Positioner (Feeler)

.062" music wire used. Wire should be adjusted so as not to snap flare hard into head. Wire should be set so if flare is properly seated in head it should not disturb flare.

4. Lead Wire Nozzles

A. Make sure there are no sharp edges or burrs on guide piece.

B. Make sure nozzles are adjusted so that they do not hit flare angle as it comes down to deliver wire.

5. Movable Stem Jaw With Escutcheon Pins (Brass)

A. Escutcheon pins were put in to relieve high strain of stem holder jaw. They raise the flare up and allow heat to wash up around inside jaw. This reduces the high horseshoe strain that would result if flare made full contact with jaw.

B. Worn or uneven escutcheon pins will cause uneven pressure on flare as well as cocking flare which will give off center mounts.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

6. Reheat Fire (position after 2nd press) - Yoke Fire

Excessive flame splash and yoke fires set too gassy allows flame splash to hit flame area in jaw opening. This causes high tension strain in the flare surface which can be readily scratched or thermal checked by the extractor jaws.

7. Mechanisms after 2nd Press out to Extractor Position

Generally there is slight possibility that mechanisms could be so far out of line as to cause movement of stem in the jaws resulting in cracked flares. It has happened that hook former was off enough to pull jaw down and then let it snap back.

There should be no movement of stem when forming wires.

8. Extractor

A. Worn face on movable jaw - Surface should be highly polished at all times.

B. Movable jaw should be set high so that the middle portion of the jaw contacts the rim of the flare thus lessening the impact on the flare when jaw snaps down inside.

C. Fixed jaws should be smooth and on center to correspond to radius of flare. Both jaws should be equidistant from flare.

D. Fixed jaws should not hit flare on the in stroke. They should be set for steepest angle of flares.

E. Standard springs used on assembly and movable jaw.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

9. Check transfer of stems and see that it does not rub jaw or hit on the conveyor chain links.

10. Conveyor Chain - Make sure there are no sharp edges on mount clips. (Glass is more readily scratched on a cooling cycle due to the fact the outer surfaces are in tension.)

11. Lead Wire Crimpers - These should be positioned so that at no time will they touch the flare on the in or out stroke. If they do touch thermal checks will result. (For mounts used on horizontal units.)

Items Affecting Fire Breakage

1. Fire breakage are those cracks which occur in the flare neck in the preheating fires before the first press.
2. Feelers (detectors) on flare neck (exhaust tube and lead wire activator switches).
   A. Make sure there are no rough edges or burrs.
   B. Make sure they are positioned properly with a minimum of pressure to activate.
3. Preheating Fires
   A. First two fires should be positioned low enough to get some flame splash up inside neck.
   B. Each succeeding fire should be hotter during the preheating. (Glass goes into tension on cooling.)

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

3. C. Important to minimize this shrinkage because slight cracks will partially seal over and crack out later at sealing or on exhausting. Also, leads will sputter around as they burn up. Particles of metal will adhere to press matrices and surrounding stems thus they will be embedded causing highly strained surface imperfections due to different expansion rates and can crack out later at sealing or exhaust. Some (608) cracked stem presses are due to burnt lead wire particles.

4. After checking Automount setup for defects and fire breakage continues, check flare necks for defects such as poor cuts (cold cuts), lack of fire polishing, cracks at cut, chips and check marks (thermal cracks). Check marks in the neck (E3 machine) usually due to small cutter hitting glass inside.

Dumet

A. Fires - No direct hot fire on dumet after first two fires. (Excess heat will burn the borate oxide layer off and blister the thin copper sheath. Dumet will look black and bubbly - Short flares a cause also).

B. Dumet lead should not turn incandescent in color before the first press to prevent burnt and bubbly condition.

C. Color of Dumet - Dumet should never be a dark red-purple color. This indicates that a heavy oxide layer remains undissolved between the glass and the wire which may break

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

C. away or become very porous. The strength of the glass to metal bond is determined to a large extent by the amount of oxide left remaining on the metal. As this layer of oxide becomes thinner, the strength is increased but only to a point where the layer is very thin (salmon pink-straw color). If it is completely dissolved to the brassy color, bubbles will occur which might weaken the seal. Ideal color is salmon pink to straw. Insufficient heat after first press will not dissolve this oxide layer resulting in the dark red color.

D. First Press - Make sure the press is closing the glass together around the leads. This protects the dumet as well as starting the glass to dumet seal as soon as possible to dissolve the oxide layer into the glass. The first press matrices are grooved so that the glass will be pressed on either side of exhaust tube.

Items Affecting Broken Exhaust Tubes

1. If exhaust tube ends are rough fire polishing fires will be used. Corning autotherm tubes are pre-glazed and do not need fire polishing.
2. Tubes are loaded approximately 1/2 to 1 mm above the end of flare (determined by specification for length of exhaust tube from flare rim).
3. Cracks occurring inside well parallel to exhaust tube can be caused by broken ends as tubes are loaded. These can be

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

3. detected by looking at the press and checking the interface of exhaust tube and neck to see if it is jagged.

4. Off center exhaust tubes cause bunching of the glass and sharp angles resulting in non-uniform geometry.

5. Weak joints will occur if exhaust blowers are out of line. If No. 1 X-blower is off that means no pre-blowing of blowhole and the exhaust tube will flare out too thin before the blowhole pushes out in the No. 2 X-blow position.

6. Burners used for heating flare and exhaust blowers should be run with hot hard fires for maximum heat. This assures hot glass working for belling. If they are run fluffy or blow out, the forming air will chill the glass resulting in insufficient belling.

7. A tight or too high second press will push up excessive glass around area for blowhole resulting in colder glass which will not be blown out properly.

8. Lead wire separators bent or sticking will cause wire to fall inside against exhaust tube, also nozzle could be off enough to drop wire inside separator.

9. Line-up of exhaust tubes with flares and mechanisms should be done while machine is hot.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

Basically caused by poor geometry of high tension strain or a combination of both.

1. Line-up of stem heads important for centering of exhaust tube with flare for good symetry.
2. Burners - All burners should be in good condition, that means clean screens and burner holes. Uniform flame pattern important, plugged burner holes results in loss of heat with poor distribution and unbalanced heating.
3. Proper balance between burners means:
   a. Equal heat on each side of stem.
   b. Equal distance (spacing) from center of weld block.
   c. Equal height on each side.
4. Observe flare neck as it is sealing - After the first two preheating fires the heat progression should be such that by the time the position before the first press is reached the flare neck will start softening and move inward at the bottom as it moves into the first press position.
5. First press position - The flare neck should press in readily with no sharp lines showing. Looking from the side the neck should show round contours. From the front the flare neck should fan out at the bottom.

The matrix plates are .235" - .240" in width and are grooved to fit around contour of exhaust tube in order that the glass will be pressed close to the lead wires to protect the dumet. The groove should be enlarged for 201 exhaust tubes. The matrix plates should

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

be set low to clear the weld blocks by .010" on closing.

The distance between matrix plates when closed should be somewhere between 2 and 3 mm.

As the neck of the flare is being pressed observe the top of the exhaust tube and lead wires for movement. If matrix plates are not centered exhaust tube will be deflected off center line. Check this from the front and the side of the press.

Worn linkage on press assembly will cause uneven press (a wedge shape press). A wedge shape press can cause a difference in dumet color from one lead to the other.

Misalignment of first press can cause uneven distribution of glass which may affect the shaping and forming of the blow hole and belling area.

6. Heating After First Press - The fires are positioned such that the heating will be concentrated at the center of the (flat) pressed section of the neck, (fan-shape as seen from the front).

The sealing process starts the bottom edge of neck and fan-shape edges drawing in and up joining the exhaust tube and flare glass around the leads.

Observe the outlines of exhaust tube and flare glass as it advances through each fire and you will see that as the glass melts together a V-shape void area is formed between the lead wire and exhaust tube on each side. These void areas will move upward as the sealing progresses so that the points of the void areas will

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

6. be just above the top of the second press matrix plates at pressing. This assures you that the glass is hot enough and will not be cold at pressing.

7. Second Press

A. The matrix plates of the second press have V-slots in them on the top side. These are for the centering of the blow-hole. Observe the V-slots on pressing, they should be centered between the leads, if not they will cause the blow-hole to shift off center following the V-slot position. (Look for off center blow-hole.)

B. The matrix plates should be set to clear the weld blocks by .005" to .010". (As close as possible without rubbing.)

C. Pressing of glass should be slight. A tight press will push glass up into area where blow-hole will be formed and increase the mass of glass that has to be worked in shaping and belling around the exhaust tube joint. The glass should show the imprint of the V and the leads move outward slightly. Insufficient pressing will result in excessive sagging downward of press area during blow-hole forming which can cause enlarged blow-hole cavities, weak joints or distorted presses.

D. Check for movement of exhaust tube on pressing from the side. This will indicate centering in and out. If press is off center, glass will be offset on one side. This will cause poor belling and sharp angles around exhaust tube joint.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

7. E. Worn linkage will cause a wedge-shape press. This can affect glass distribution on belling resulting in sharper angles and non-uniformity.

8. Fires after Second Press

A. First fire after second press (reheat fire) is run gassy to heat up the well area along with pressed area of the stem in preparation for the belling of the stem.

B. The burners are positioned higher to center heat on the junction at top of pressed area in the flare blower positions because this is the base of the well area where the blowhole will be formed and the flare glass belled out.

C. Make sure the fires are the same height inside and out to assure uniform belling on both sides.

D. Uniform heating condition will be shown by the blowholes. Blowout will occur on both sides of the mount alternately along with double blowholes occasionally. If not, heating is not balanced and burners should be checked for height and balance of heat in and out.

E. Last set of fires (glazing or burnback). These fires should only be hot enough to burn back the lip of the blowhole. Excessive heat will cause the stem press to sag and distort in the next two positions or when the weld blocks open (exhaust tube air will force press down and back on weld block causing glass to stick). The

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

8. E. strain in the press will also change due to rapid cooling on bottom end of press. This can cause high tension inside blowhole leading to vertical 608 type cracks.

F. Burners used for heating forming air (flare and exhaust tube blowers) should be run hot (sharp hot gas-air fires) to assure maximum heating of air. This aids the belling of the stem as cool air will chill the surface of the glass and make it harder to achieve well rounded contours.

9. Stem Blowout and Belling

A. Observe the glass from both directions front and side. The glass should flow down readily and should see movement on both sides as the well area is formed.

B. First flare and exhaust blowers position. While the well area is being formed the exhaust tube air starts the blowhole cavity at the base of the exhaust tube. A small bubble should be started to counteract the flare blowing air as well as holding the exhaust tube glass from thinning out at the joint. This position is balanced against the next for blowhole size and shape.

C. Second Flare and Exhaust Blower Position - Belling is maintained to hold shape of well area and balance against the exhaust tube air. The blowhole should not blowout immediately on indexing into this position but about half way of the time in position it should blow out.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

9\. D. Flare blowers should be positioned approximately 1/8" away from exhaust tube. The hole (.070") in the blower is drilled at a 5^o angle; (you can check direction by inserting a .070" drill), the air should hit the exhaust tube down inside well of the stem. The final position of the blowers is determined when uniform belling of the stem is observed. The flare blowers should be level and not tilted up or down and should be centered on the exhaust tube. All of the blowers should be the same distance away from the exhaust tube and be in line when sighted from the side.

E. Exhaust tube blowers should be centered approximately 1/16" to 1/8" above exhaust tube. Check the line up from both the front and the side.

10\. Cooling Setup for Standard 61-Head Chassis - Speed 2500/Hr.

A. Main line air pressure should be 5 lbs. for adequate cooling during hot weather months.

B. Positions 26 and 27 have heated exhaust tube blowers. Only enough air is used to hold the shape of the exhaust tube joint area while the glass starts to cool. Make sure there is no movement of the press or well area in these positions. This would indicate too much air or glass excessively hot which could lead to sharp angles (cracked stem presses).

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

10. C. Positions 28, 29 and 30 have flare blowers and air is blown through the burners. The flare blower air is opened wide (flowmeter setting .7 or .8 CFH). This cools the inside well area and exhaust tube joint. The air blowing through the burners cools the outside press area. The valve handles are opened 3 full turns. It is good practice to blow out the burners and blowers once a month to assure maximum cooling air. The cooling rate of the stem is important in relation to the temperature of the press area when it reaches the yoke fires. Make sure the burners are equidistant from center line of press and air flow should be concentrated on the thick press area rather than the well area.

D. Positions 31 through 41 - The stem press is allowed to cool natural so that it will be just above the strain point going into the yoke fires. You can check this by removing a mount before it goes through the yoke fire and checking it immediately in a polariscope (polariscope should be set up close to machine so mount can be looked at as it is removed from stem jaws). You should not see any strain in the press area. If you do the mount is cooling too fast. This would indicate a lack of heat in the stem forming section rather than excess air cooling.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

10. E. Care should be taken to see that nothing upsets the normal cooling cycle such as drafts from operator blowers, air from wire cutting position or flare glass removal jet. Also nothing should touch the well or press area such as cold glass (fire breakage hung up on mechanisms) or metal contact from the lead wire separator or former hitting press. All of these conditions cause sudden localized chilling which will cause high strain that the yoke fire setup will not take care of.

11. Yoke Fires

A. The purpose of the yoke fires is to reheat the junction between the thick press glass and the thinner well area glass along with the exhaust tube joint area. This is done to heat the glass up above the strain point (400°C) in preparation for the rapid cooling which will set up a compression surface inside the well area around exhaust tube and lead wire joints.

B. The heat of the yoke fires should be concentrated at the center of the press junction where the glass starts to bell out (above the center line of the blowhole).

C. The fires should be centered on the stem press, equidistant from center line of press and level from side to side.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

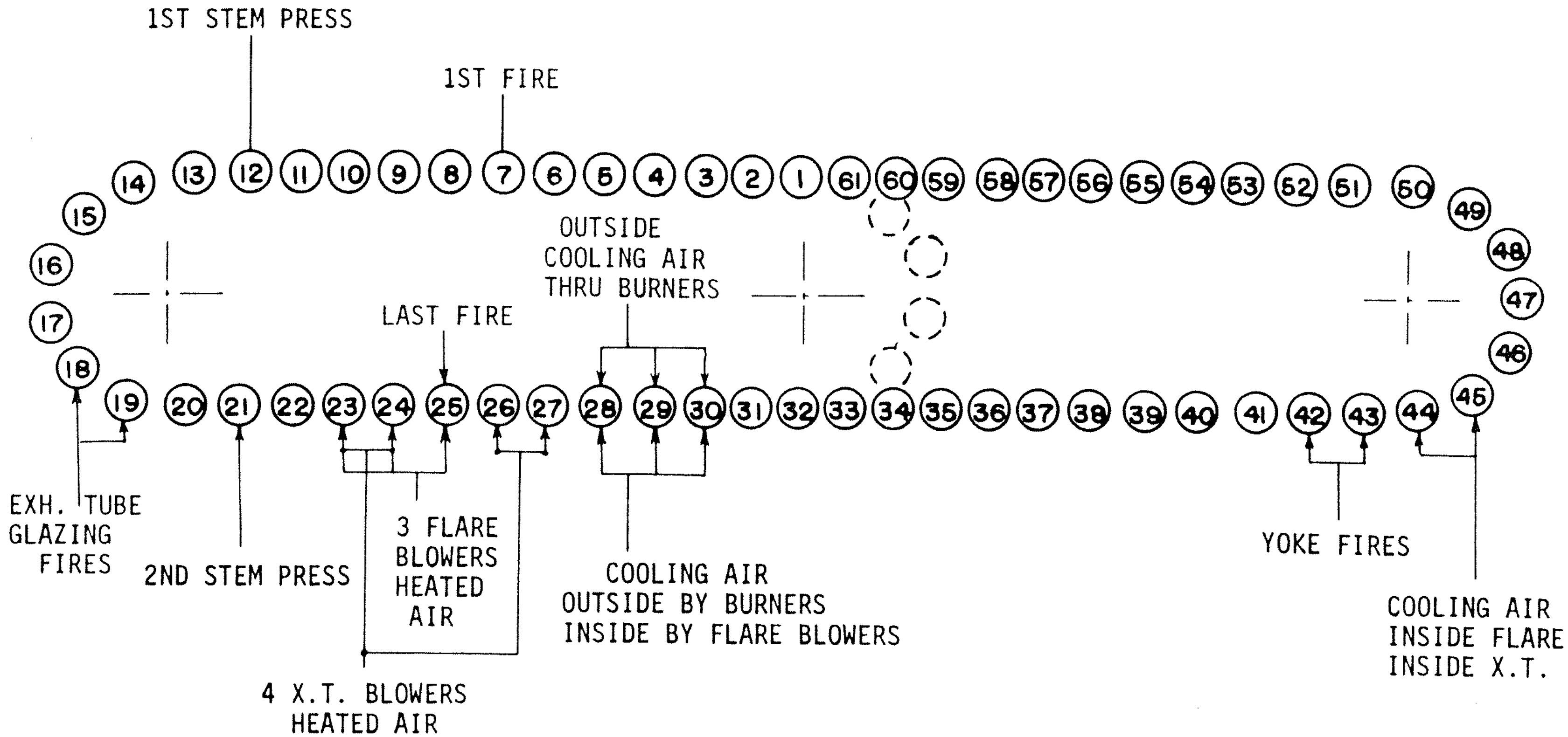
11. D. To arrive at proper fire setting start out with a low gas-air fire and check a stem taken before it goes through the yoke fire and compare it with one that has gone through the yoke fire and cooling section. Observe both in a polariscope and look for a reduction of the yellow coloring surrounding the blowhole area. Then proceed to increase the heat (gas-air-oxygen) repeating point where further heat shows no change, then stop. If you proceed adding heat the glass will be too hot for the cooling air setup time resulting in no compression surface and it is possible to reverse the strain causing half moon type cracks at the base of the blowhole in the well area.

E. The final test for strength of the mount is the molten salt bath test. The temperature should be maintained at 300°C. Make sure the mounts are cooled down before testing and hold stem press and well area in the bath for a minimum of 3 seconds. After removing examine under magnifying glass observing inside the blowhole to look at each lead wire from the inside. (Majority of 608's have origins starting from the lead wire.) Standard Practice A-10A covers the details of this test. You should strive to maintain .0% failures in this test.

10.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT - (CONTD.)

12. Scratch Test (If No Salt Bath Test Available)

One of the means of knowing there the tension areas on the mount are is the scratch test. When you scratch a glass surface with a diamond tip carbide tip, or emery paper, a tension surface will scratch more readily than a neutral surface and a comp ssion surface will offer more resistance to scratching. To check if the yoke fire and cooling setup is effective in setting up a compression strain, scratch the inside well area of the mount around the junction of the exhaust tube and inside the well area (slim carbide tip is used for this). Straight line scratches from the junction of exhaust tube up the well side are sufficient. If a good strain level was attained you should not get any spontaneous cracking. If you do get cracks something is wrong in the cooling cycle. Delayed cracking after a few minutes has been acceptable for mounts used on the vertical units but you should strive to reduce the strain to a level where they will not fail after scratching as welding metal splash will crack out high strain areas left in the well area of the mount on the horizontal units.



61 HEAD CHASSIS
TYPICAL FIRE SET UP
T-12 VERTICAL MOUNTS

10.10 REFERENCES FOR ADDITIONAL IN-DEPTH INFORMATION

1. Stem Making - EDP Training Program #35 - available from GTE Sylvania, Equipment Development Group, Estes Street, Ipswich, MA 01938

2. Stem Making Process - 400 Movie - EDP Training Program #37 available from GTE Sylvania, Equipment Development Group, Estes Street, Ipswich, MA 01938

3. Stem Making Practice by R. J. Albonese, GTE Sylvania, Loring Avenue, Salem, MA 01970

4. Flare Making - EDP Training Program #30 - available from GTE Sylvania, Equipment Development Group, Estes Street, Ipswich, MA 01938

MOUNTING

11.0 Mounting is the term used to describe the actual attachment of the filament to the lead wires. The process includes forming of the lead wires, inserting support wires, hooking or looping the support wires around the filament, clamping the filament to the lead wires, stretching the coil and final shaping of the mount prior to insertion into the bulb. There are many different mount configurations C-6, C-2V, C-2R, CC-6, CC-8 etc. (See 2.2).

There are two general types of mounts:

A. Bead Mounts

B. Stem Mounts

11.1 Bead Mount

The Bead Mount is used for all microminiature, subminiature and butt seal miniature lamps. The bead mount is made on a mount mill.

Figure 11.1.0.1 is a general view of a 32 head mount mill.

The bead mount head is made up of a center spacer and a spring loaded gripper on both sides.

The general process is as follows:

1. Wire Feed

Dumet wire is fed up from two spools below the turret. The wire enters both sides of the head spacer, gripped by the spring loaded fingers. The wire is then cut to proper length. See Pos. 1 Figure 11.1.0.2.

MOUNTING

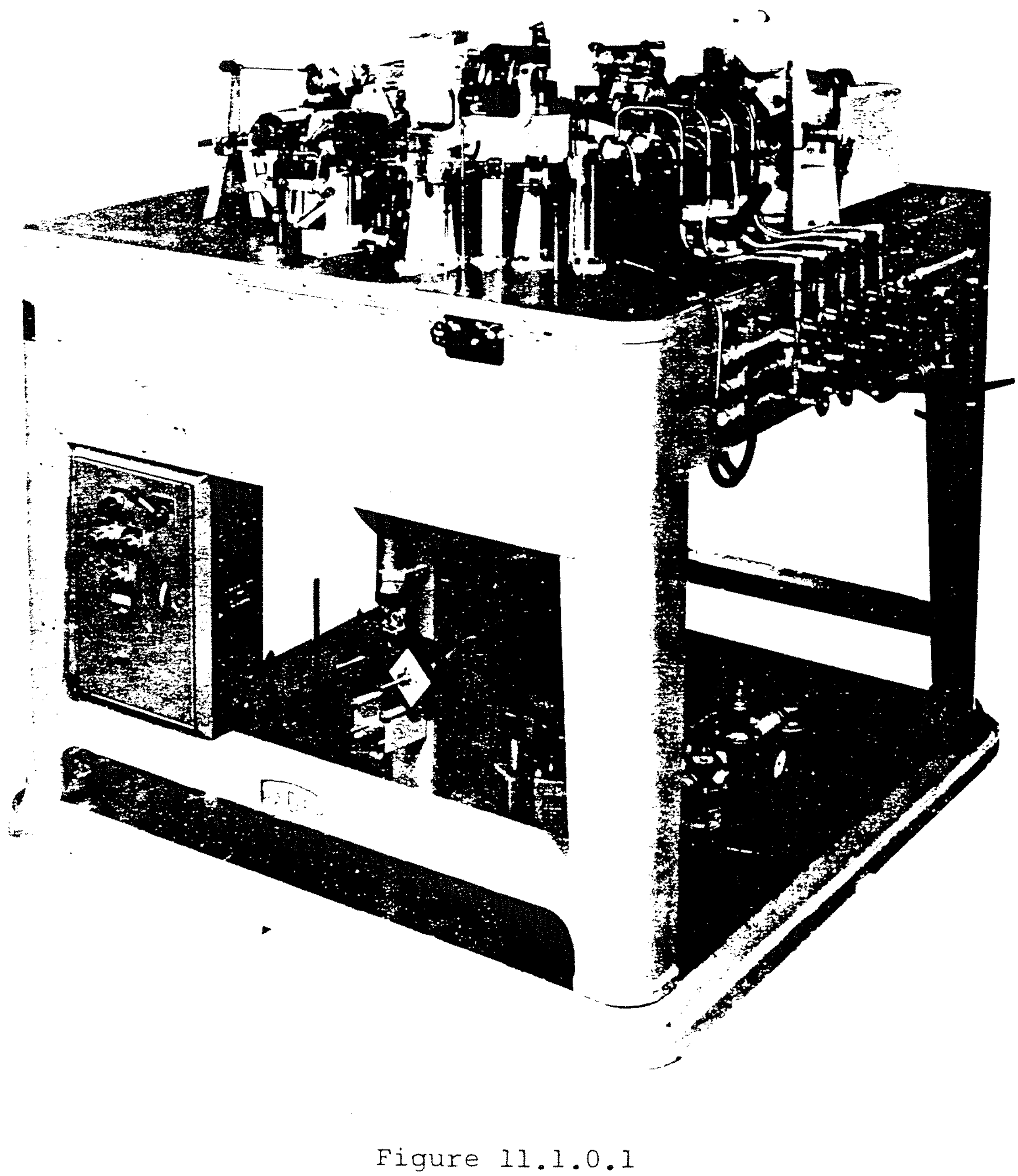


Figure 11.1.0.1

MOUNTING

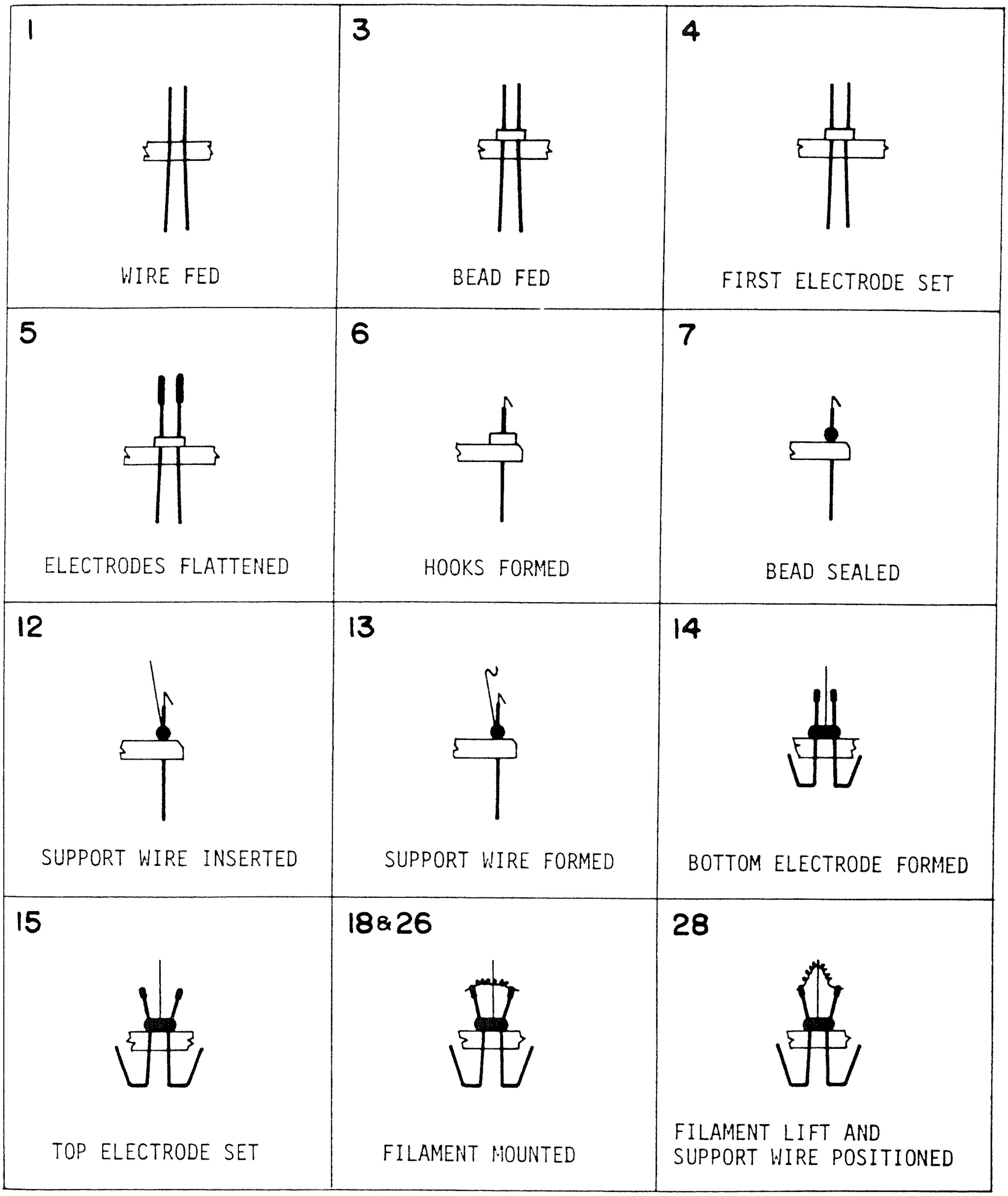


Figure 11.1.0.2

11.1 BEAD MOUNT - (CONTD.)

2. Bead Feed

A bead made from pressed and sintered glass powder is dropped over the two leads. See Pos. 3 Figure 11.1.0.2.

3. First Electrode Set

The leads are positioned to correct spacing and made parallel to each other. See Pos. 4 Figure 11.1.0.2.

4. Wire Flattening

The dumet leads are squeezed in a die to a thickness about 50% of wire diameter. The dumet is usually 10 mil. (.254mm), therefore, flat thickness is usually approx. 5 mils (.127mm). See Pos. 5 Figure 11.1.0.2.

5. Hook Forming

The pre-flattened wire is bent to form a hook. The point of bend is slightly above the middle of the flat area so that when hook is closed, the flat will extend approx. 1.5mm or more below the clamp. The hook opening is approx. 30-45°.

6. Bead Sealing

The bead is melted and sealed to dumet wire by pin point gas-air-oxygen burners. The top of bead is fused to lead wire first so that the balling of the bead will lift the bead from the head center spacer. The life of head and quality of bead will be poor if the bead is heated while heat sinked by contact with head.

7. Support Wire Inserted

The support wire is always a clean moly. The wire is fed from spools. The moly wire is inserted into the bead far enough so that

11.1 BEAD MOUNT - (CONTD.)

it will not pull out easily, but not far enough to hit dumet leads or another support wire. After insertion, the support wire is cut to length. See Pos. 12 Figure 11.1.0.2.

8. Support Wire Forming

The free end of the support wire is formed into a shape called a "Shepherd's Crook" as shown in Pos. 13 Figure 13.012. After forming the hook, the support wire is sometimes formed to a bent shape something like a question mark (?). The purpose of deforming the support is to obtain flexibility to adjust mount and filament tension later on.

9. Bottom Electrode Forming

In this operation, the leads below the bead are formed so that when inverted, the mount will hang down into bulb and be supported by the formed lower leads. See Pos. 14 Figure 11.1.0.2 and Figure 9.4.2.

10. Top Electrode Set

The leads and clamps are set to the position to receive the filament. The lead tip spacing (L.T.S.) is critical because small changes in L.T.S. make large changes in lamp current, lpw and life. Lamp current increases as L.T.S. decreases. Ref. to Chapter II for complete explanation.

11. Clean Leads and Clamps

It is important that the leads, supports and clamps be cleaned of oxides and other contaminates. To accomplish this, the support

11.1 BEAD MOUNT - (CONTD.)

wires are bent down and a hydrogen cup is lowered over the leads. The parts are heated by the H_2 fire and cooled in raw H_2 by moving the parts through the burning H_2 and into the supply H_2 deeper in the cup. The cup is raised quickly so that the H_2 flame will not reheat the parts to oxidization point. In addition to cleaning, the heating also anneals the clamps and removes the effect of cold work due to lead flattening etc.

12. Filament Mounting

The filament is transferred from a feeder and is usually held by the body of the coil. The transfer is such that the coil legs enter the hook leads. The filament is held while the clamps are closed on the coil legs. Clamps are not the only way coils are attached to leads. See (11.3.7), (11.3.8) and (11.3.9).

13. Position Support

There are various methods of getting the filament into the support loop. One way is to lift the filament and then lift the preformed support wire with "Shepherd's Crook" such that the hook pocket is directly below the filament. Then drop the filament into the support hook. If the filament geometry is such that the coil is not "springy" and takes a set when stretched, then the support loop is pushed under the coil and then lifted.

After the coil is in the loop or hook, the loop is closed by bending over the free end of the support lead. The filament should be in the support loop opposite to any opening in the loop. If the

11.1 BEAD MOUNT - (CONTD.)

loop is not closed and filament not deep in loop, the filament may become free of support if filament sags or becomes loose for any reason.

14. Final Mount Set

The final step is to firm up the mount geometry and adjust the stretch in filament, etc. If getter is going to be applied to the leads, this operation is also done in the final stages of the mount mill.

15. Unload

The mount mill can unload complete bead mounts into a collection box, transfer to mount conveyor or insert mount directly in neck of bulb, depending on the type of mount mill and lamp production line.

11.2 Stem Mount

The stem as it leaves the stem machine or stem making section of an automount has the two leads straight and in the same plane. If the stem requires a glass support button, an extension of the exhaust tube beyond the press is provided. Figure 11.2.0.1 shows the complete stem for GLS lamps ready for the mount machine.

The general cycle for mounting a CC-9 (European type) GLS lamp is as follows:

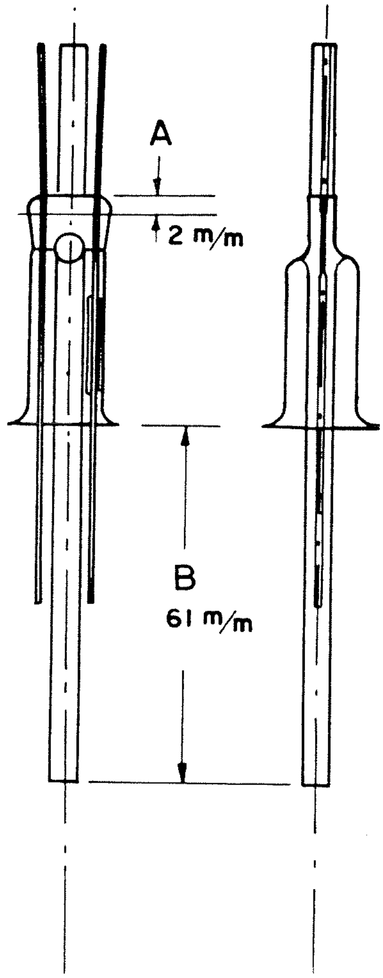
1. Steam loading or in case of Sylvania automount indexing into mount area of automount.

2. Spread Lead Wires

The lead wires must be positioned correctly for ensuing processes and also to free area of glass rod extension.

32 HEAD STEM MACHINE

15 - 200 WATT LAMPS



**DIMENSIONS A AND B
ARE IMPORTANT AND APPLY
TO ALL STEMS FOR LAMPS
MADE ON THE SEALEX GROUPS**

Figure 11.2.0.1

11.2 STEM MOUNT - (CONTD.)

3. Apply Heat for Button Forming

a) The first burner after the feed-in is for glazing the rough end of the glass rod to prevent chipping or cracking on later stages.

b) The first pair of heating burners are set to point approximately 2 mm. from the end of the rod.

c) The second pair are set 1 mm. from the end of the rod.

d) The third pair are set on the end of the rod.

This ensures that the glass is thoroughly melted to form a stud. If the glass is not melted high enough the stud will not form correctly and may crack off. If the glass is melted too high no stud will form as the end of the rod will form into a blob of glass. Overheated glass will allow the pigtails to slip out on cutting the molybdenum wires. Too cool glass will either cause the molybdenum wires to point upwards or again slip out of the glass because it has not been sufficiently soft to flow around the wires.

4. Form Button

The button is formed by pushing on heated end of tube and collapsing the softened area of glass. Figure 11.2.0.2 shows a stem with spread leads and formed glass button.

Figure 11.2.0.3 shows the general form of the completed glass button.

MOUNTING

Figure 11.2.0.2

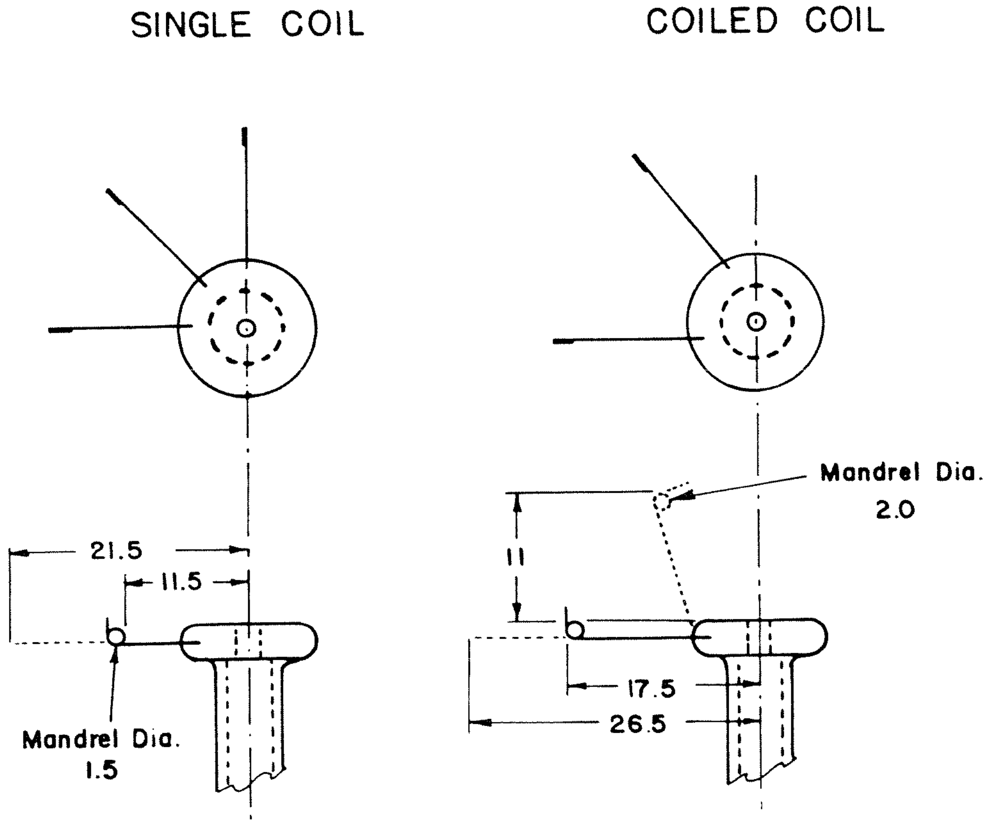


Figure 11.2.0.3

11.2 STEM MOUNT - (CONTD.)

5. Flattened Lead Wire

The upper section of the lead wires are flattened to approx. 50% of the original diameter. This will be the area where filament is attached. The flattened leads will make better contact to tails of filaments.

The flattening unit consists of two hammers and one anvil. It has a fixed stroke. Special care must be paid that the flattened ends have the right width. This unit flattens the ends of the inner leads.

The hammers must be so adjusted that the flattened portions have the same width all over. In the long run grooves will wear into the hammers and anvil. As a result, the flattened ends will no longer have uniform widths, causing the hooks to get skew in many instances when bent. The anvil should be at a perfectly right angle to the axis of the hammer.

6. Hook Forming

The flattened area of the leads is bent or formed into a clamp hook. The point of bend is somewhat above the middle of the flattened area such that when the clamp is closed the flattened area will extend approx. 1 mm. or more below the clamp. The clamp hook opening is approx. 45^{o}.

7. Coil Feeding and Clamping

There are several kinds of coil feeders, but they have one thing in common. They all present the filament tails to the lead clamp hooks. The filament is held in position by the coil transfer

11.2 STEM MOUNT - (CONT'D.)

mechanism and the filament tails are clamped in the lead wires. The coil must be so inserted so that there is the required amount of tail overhang or in some cases the tail end must be flush with the clamp. A change in coil overhang will affect lamp watts, life and lpw.

11.3 JOINING THE FILAMENT TO THE LEAD WIRES.

Filaments may be joined to the leads by hook clamping, by pressing the tungsten filament into the leads, or by welding. Regardless of the method used, the filament joints must be made strong enough to withstand all shipping and lamp service requirements, and tight enough to provide good electrical contact.

Poor contact introduces high and variable resistance, which is likely to cause severe inconsistencies of rating and life. The lower the voltage and the higher the current of the lamp, the greater these effects become. This is because the voltage drop, which occurs at the filament joint, becomes a large percent of the total lamp voltage. Also, when the nature of the mount structure is such that an appreciably large percent of the total heat loss from the filament is by conduction through the leads, any variations in heat-flow resistance at the juncture-points cause undesirable changes in lamp performance.

Another factor which affects end losses, and consequently lamp performance, is the length of legs at which the filament is mounted. Here again, the magnitude of the effect on lamp performance varies

11.3 JOINING THE FILAMENT TO THE LEAD WIRES - (CONTD.)

with mount structure, and is usually greatest among lamps of low voltage and high current design.

Leg length is also an important factor in determining and controlling total length of lighted filament wire. Variations of this kind cause pronounced variations in rating and life, depending, to a large degree, on the percentage of the total length of filament wire involved. For this reason, short filaments are more sensitive to slight inaccuracies of mounting than long filaments. Every effort should be made to keep the length of the legs as accurate and as uniform as possible.

In the process of joining the filament to the leads, it is important that the filament be held and joined in such a manner as to avoid introducing stresses in the coil. Such stresses tend to warp the coil, and may affect the appearance and performance of the lamp.

Aside from the above, each individual method of joining the filament to the leads has its own particular problems.

11.3.1 HOOK CLAMPING

Hook clamping can be used most successfully in applications where the filament has coiled ends, or where it has straight ends but is of large enough diameter wire to give good surface contact in the clamps. When used with straight-end filaments of small diameter wire, hook clamping usually gives rise to non-uniform or high resistance contacts, and is therefore not very well suited to this class of lamps.

11.3.1 HOOK CLAMPING - (CONTD.)

At best, hook clamping requires very close control in order to obtain good quality results. The following items should be observed:

a. The clamping surfaces should be clean. Oxides, dirt or borate coating cause high resistance contact, and are undesirable. They should either be avoided or should be cleaned off as well as possible by subjecting the lead tips to a reducing flame, or by heating them in a reducing atmosphere.

b. If the hook sections are flattened, the width and thickness of the flats should be uniform and accurately maintained. Non-uniformity of flats result in inconsistencies of surface contact with the filament, and inconsistencies of clamping pressure, either of which may affect contact resistances.

c. The hook should be sharp, and the hook should be closed sufficiently tight so that little or no light can be seen throughout its length. Filaments having a straight end section should be clamped especially tight to insure good electrical contact. When tested with the fingers, there should be no wiggle or movement of wire in the clamp. On the other hand, clamping should not be so tight as to fracture the filament wire.

d. The filament, on the coil side of the clamp, should be placed as high as possible in the hooks. A coil near the open end of the hook will tend to keep it open and may not be well secured. Sharp bends should be avoided.

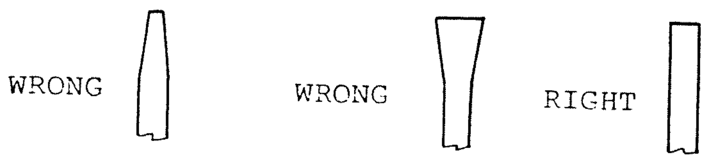
11.3.1 HOOK CLAMPING - (CONTD.)

e. The two surfaces of the hook should meet squarely and coincide without "scissoring", which may cause variations in contact resistance and makes it difficult to control lighted length of filament wire.

f. Generally speaking, it is better to use a slow-pressure clamping action than a hammering action. This gives the metal a chance to more or less flow and set before the pressure is released.

11.3.2 LEAD FLATTENING

The first step in preparing the leads for clamping is to flatten the section of the lead to be used to form the hook. The flattening serves to get more contact to filament as well as to control final closing of the clamp. The lead usually is flattened to reduce lead diameter by 50%. The flat must have uniform width.



11.3.3 HOOK FORMING

The second step is hook forming. There are two types of hooks. For leg type single coils and some continuous coils, the hook is simply a sharp bend of the lead wire leaving about a 45-60°

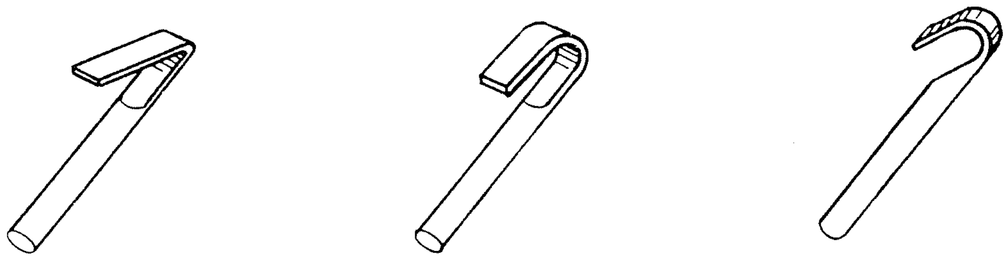
11.3.3 HOOK FORMING - (CONTD.)

opening. For large coils, the bend is formed around a pin resulting in an open loop. Hooks are usually annealed after hook forming to eliminate or reduce spring back at clamping.

Sharp Bend Type Hook

The general shape of the hook is either that of a "V" or parallel. The "V" style is standard and can be tailor made to accommodate the diameter of the filament being clamped.

Styles Of Lead Wire Hooks



"V" Parallel Sheared Hook

11.3.4 GENERAL RULES FOR HOOK CLOSING

The closing of the hook on the coil requires careful attention. A rule of thumb for vacuum lamps is to close the clamp to twice the flat thickness minus .001". This serves to break through the oxide on the copper or dumet lead and spray getter on coils so processed. Loose clamps in vacuum lamps have been the cause of arcs. Gas-filled lamps present problems where the tungsten in the coil is larger and wound on larger mandrels. These coils are clamped too tightly if

11.3.4 GENERAL RULES FOR HOOK CLOSING - (CONTD.)

the cross-section of the coil in the clamp starts to form a Figure "8". This leads to a lamp that will not survive much of any bump. A rule of thumb here is to clamp to twice the flat thickness plus 70% of the coil diameter. On high ampere street series, 15 and 20 amps, to assure a good electrical contact, a minor coil is slid over the straight end of the coil. This will allow for considerable pressure in the clamping jaws. On low ampere street series using nickel leads, the hook portion is warmed by passing current through the clamp while the coil lies in the hook. When the tungsten is warmed, broken filaments are kept to a minimum throughout the life of the lamp.

11.3.5 OPEN LOOP TYPE HOOKS

The high wattage types, like the 300 and 500W C9 mounts, have the coil held in position by wrapping the lead around the coil and holding it in place like a vise.

"Wrap Around" Clamp

Conventional Clamp

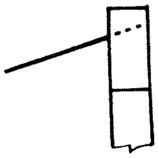
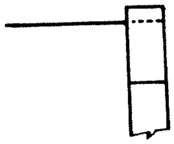
On lead wires larger than .050" diameter, the hook is formed after a portion of the end has been milled off and is known as a "sheared" hook. See 11.3.3.

MOUNTING

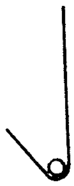
Inspection of Clamps

Incorrect  Correct 

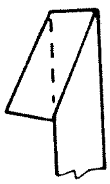
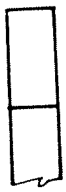
Flattened end must have prescribed width. Coil must be clamped STRAIGHT.

Incorrect  Correct 

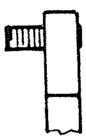
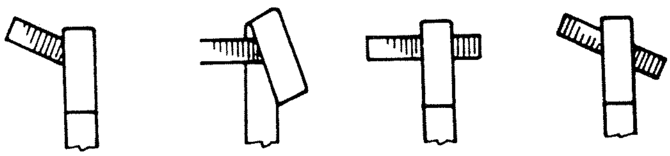
Coil must be inserted as low as possible into the hook on the mounting machine.

Incorrect  Correct 

Flattened end must be straight.

Incorrect  Correct 

The filament legs should be all the way through the clamp. Excess overhang should be avoided.

CORRECT CLAMPING	INCORRECT CLAMPING
	

11.3.6 INSPECTION OF CLAMPS

Clamping-In of Coil

Coil leg must NOT protrude from flattened end of lead nor be half-flattened. Leg should be just visible. Flattened end must be closed.

11.3.7 PRESS JOINTS

Pressed joints, wherein the filament is pressed into the lead wires, are used most successfully in applications where the filament is of relatively small diameter wire and has straight wire legs. Pressed joints usually give a lower and more uniform contact resistance than hook-clamping, and therefore result in more uniform rating and life. This method is particularly advantageous for radio panel lamps, which, if hook-clamped, frequently give rise to radio interference.

11.3.8 GENERAL RULES

The principal quality considerations to be observed in making this type of joint are as follows:

a. The lead tips should be very clean. Oxidation is particularly bad in that it materially reduces the pull-out strength of the filament. Any oxide, dirt or borate coating should be cleaned off as well as possible by subjecting the tips to a reducing flame, or by heating them in a reducing atmosphere. On emerging from this treatment, the surface should have a clean metallic appearance.

11.3.8 GENERAL RULES - (CONTD.)

b. When examined under a microscope, the filament should be sufficiently encircled by the lead-wire metal to lock it into place.

c. The amount of pressure to use is that which gives the strongest joint without fracturing the filament wire. Experience indicates that best results are usually obtained if the clamping pressure is approximately that which is required to reduce the thickness of the flattened portion to approximately one-half of the original diameter of the lead.

d. A pull-test is recommended as a means of determining the pull-out strength of the filament. This test should be used frequently enough to insure maintenance of good quality joints.

e. Strength testing of press joints should be done on finished lamps by placing the lamps in a bottle and shaking on a shaker device.

f. The strength of the joints on some lamp types may be checked with an electronic noise tester. This should be used to insure a good quality produce.

11.3.9 WELDED JOINTS AND CLAMPS

Welding is done by pressing the filament against the lead and, at the same time, passing a large momentary current through the point of contact to fuse the metals together. This makes a very low resistance joint, but the extreme temperature tends to crystallize the filament at and near the juncture and weaken it.

11.3.9 WELDED JOINTS AND CLAMPS - (CONTD.)

Welding is not well adapted to automatic mounting, and it can be used successfully only with certain kinds of leads. Welding is confined to hand mounting of lamps which employ relatively large nickel leads.

On some lamp types, such as butt seal mine lamps, in addition to clamping using hook leads, the clamp is welded.

11.3.10 GENERAL RULES FOR WELD JOINTS AND CLAMPS

Good welding is obtained only when the following variables are correct and under close control:

a. Amount of current used.

b. Duration of current flow.

c. Pressure used on welding jaws.

d. Condition of the surfaces to be welded.

The amount of current needed to make a good weld varies with the diameter of the nickel and tungsten wire to be welded. The larger the nickel or tungsten, the greater the current needed. The best welding conditions are obtained by using a large amount of current for a small time, usually one-tenth of a second or less. Too long a time results in brittle filaments; too short a time in insufficient fusion of the metals.

It is essential that the transformer have sufficient capacity for the job at hand. Good welding can be done using a transformer with higher capacity than is needed, but good welding cannot be done if the capacity of the transformer is too low. The open-

11.3.10 GENERAL RULES FOR WELD JOINTS AND CLAMPS - (CONTD.)

circuit voltage affects the time-current relationship and is therefore important. For best results, this should be of an order of about 5 volts. If double electrodes are used, the electrical wiring should be such that the filament does not shunt off some of the welding current, since this causes additional heating and crystallization at the joints.

The welding jaws should be set to close and apply full clamping pressure before the timer is triggered. Occasional readjustments may be needed to compensate for wear. The welding pressure should be uniform and accurately controlled; hence anything which imparts a drag to the welding jaws should be avoided. The amount of pressure to use is that which gives best results. Ordinarily, this will be approximately 10 to 25 ounces. Too low a pressure causes burning and increases sparking; too high a pressure requires too high a welding current which increases brittleness.

The size and general design of the welding jaws has an important bearing on the quality of the weld. The jaws must be large enough to prevent overheating and sticking of the weld specimens to the jaws, and to allow sufficient welding area, but not so large as to be awkward. The electrode tips should be parallel, and should be kept smooth and clean. Copper electrodes oxidize quickly and wear rapidly, so it is better to use a suitable alloy.

In order to prevent excessive oxidation of the nickel, it is necessary that the involved area be flooded with a reducing gas at

11.3.10 GENERAL RULES FOR WELD JOINTS AND CLAMPS - (CONTD.)

the time of welding. A jet of hydrogen, synchronized to turn on shortly before the closing and then turn off shortly after the opening of the welding jaws, can be used successfully for this purpose.

A weld which has been properly made will have the tungsten partially embedded in the nickel, and the nickel flowed up and around the tungsten to partially encircle it. If viewed under magnification, the nickel at the junction will appear smooth, showing that it had reached a stage of fluidity. Ordinarily the weld should withstand sufficient pull on the filament to straighten the coil before breaking away. Fractured filaments are difficult to detect by visual inspection. An electronic noise tester has been designed for this purpose and should be extensively used to insure good quality product.

11.3.11 LEAD WIRE TURNERS

Turning of lead wires is done mainly if the coil is not at right angles to the leads. This does not apply to vacuum coils.

In this operation, the mount holder must sink and the flattened ends should get into the forks. There are three sets of forks for different thicknesses of inner leads having increasing slot widths:

for all C.C. and S.C. up to 100W - 0.6
for all S.C. 150 - 200W - 0.9
for all S.C. 150 - 200W H. V.
for all S.C. 200W L. V. with mandrel.

11.3.11 LEAD WIRE TURNERS - (CONTD.)

NOTES:

The forks must be so fitted that the slots are parallel to the radius of the turret drawn to a point midway between the forks. This can only be adjusted correctly if the forks do not move when slightly turning the drive belt. As to level, they must be at such a height that the tip of the flattened end cannot touch the bottom of the notch. The lead-wire turners can move right and left.

11.3.12 SUPPORT WIRE INSERTION

The support wire is clean moly wire. GE type KW is often specified. KW is doped moly that does not recrystallize as readily as undoped moly.

The insertion process is accomplished by heat softening the support glass button and inserting one or several moly wires into the glass button.

Each support wire causes local cooling of the filament and reduces the light output by about 1%, therefore, the number used is kept to a minimum.

The maximum length of filament between supports depends on its mechanical strength to avoid sagging; this in turn depends on minute proportions of other metals added during preparation of the tungsten and on its molecular structure. The heat treatment of the filament, both before and after it is coiled, is of major importance also. The greatest care is, therefore, devoted to these matters during filament manufacture.

11.3.12 <u>SUPPORT WIRE INSERTION - (CONTD.)</u>

The inserting heads should be adjusted so that the support wires are inserted into the hub or button to a depth sufficient to anchor them securely in the glass.

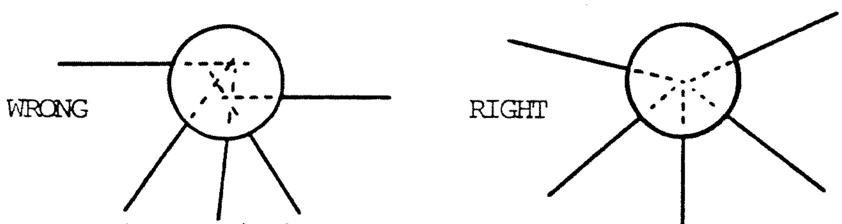
The clearance between adjacent support wires in the hub must be not less than 1 mm, otherwise short-circuiting of sections of the filament may occur. The supports must also be properly spaced and positioned.

The supports must not protrude above the surface of the glass button as this may lead to 'tracking' across the button face.

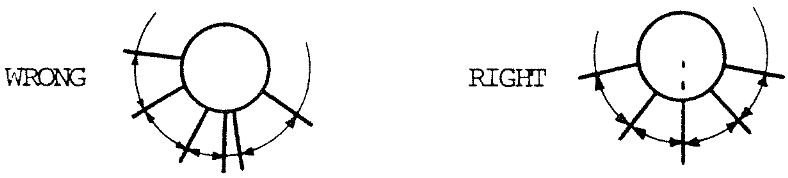
11.3.13 <u>GENERAL RULES FOR SUPPORT INSERTION</u>

Inserts must not be put too deep into button as this may cause short circuit, nor too shallow, when the pigtails may come out of the button.

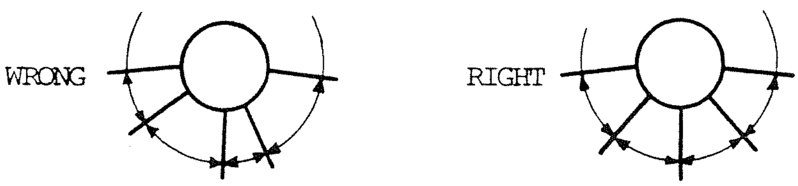
Pigtails must point at button centre



Button and insert (spider) must be symmetrical to leads



insert spacings must be uniform (uniform distribution)



11.3.13 GENERAL RULES FOR SUPPORT INSERTION - (CONTD.)

The lead wires must be correctly positioned with respect to the insert button. This is necessary to prepare the filament for attachments of supports.

11.3.14 ASSEMBLING SUPPORTS TO FILAMENT

The moly support wire is formed around the filament as shown in Figure 11.3.14.1.

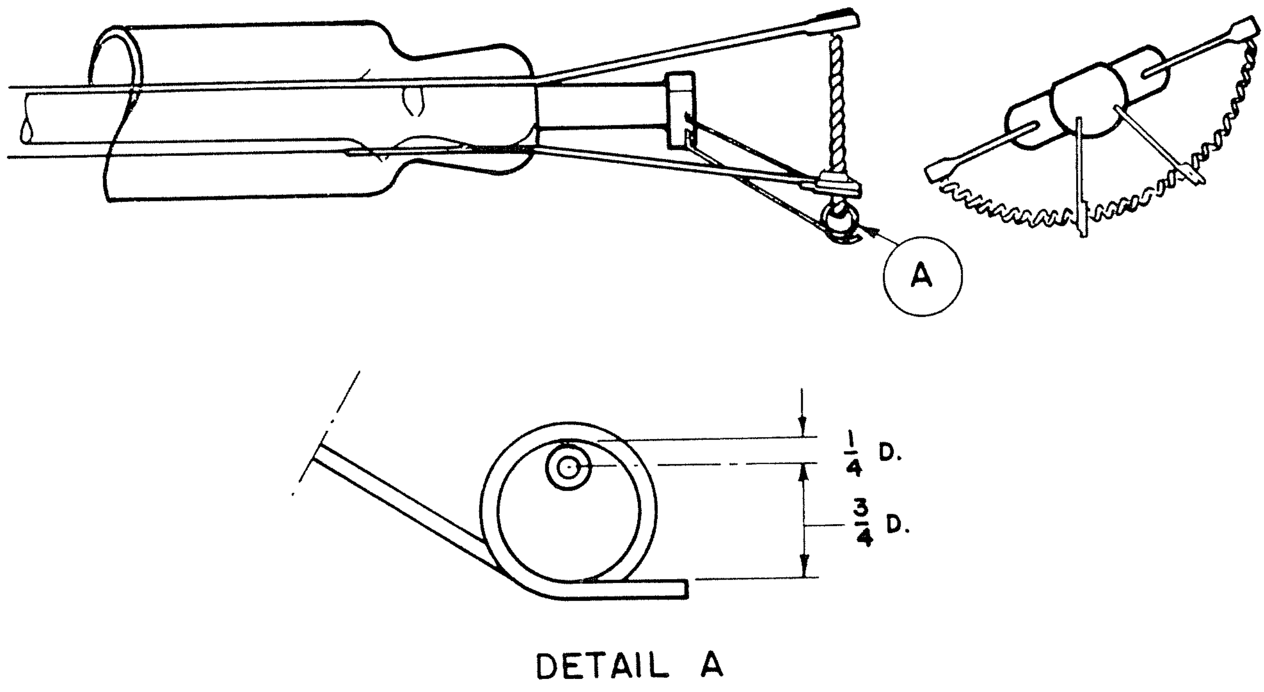


FIGURE 11.3.14.1

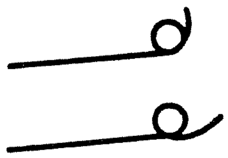
11.3.14 ASSEMBLING SUPPORTS TO FILAMENT - (CONTD.)

There are two common methods of looping the support wire around the coil. In one case a curling die is used where in the support wire is pushed up against a curved polished surface such that the wire deflects and is effectively turned back around the coil. The other common method is a device that locates the coil in a slot in a pin such that the support wire can be wound around the pin and then the pin retracted and moved away from the filament leaving the support wire looped around the filament. This device is a multiple head that wraps all supports at once. The loops are often called pigtails because of their shape.

11.3.15 GENERAL RULES FOR LOOPING SUPPORTS AROUND FILAMENT

Pigtail rolling:

Ring and vee (zigzag) filaments:
tails as short as possible.



Pendant ring filaments:
tails slightly longer than for vee filaments.

Pigtails must be closed:

WRONG

RIGHT

11.3.15 GENERAL RULES FOR LOOPING SUPPORTS AROUND FILAMENT-(CONTD.)

The pigtails should be correctly formed to prevent the filament from becoming disengaged. The plane of the pigtails should be perpendicular to the axis of the filament to prevent short-circuiting of turns.

11.3.16 COMMON PROBLEMS, CAUSES AND CURES

Straight pigtails may be produced if:

mandrel has worn;

hammer is worn;

molybdenum is short;

roller has been grooved.

Short Pigtails or Pigtails Not Rolled Completely If:

molybdenum has a twist.

Roller Element - Common Defects

In rolling pigtails the following defects may occur in the case of Single Coils:

1. The pigtail is not pushed off the mandrel, the wire being pulled straight by the jaws.

   a. the segment does not turn far enough: the lever controlling the segment must then be adjusted.

   b. a groove has worn into the roller, the wire getting stuck in the groove and being riveted so tightly round the mandrel that the pigtail sticks to the mandrel.

11.3.16 COMMON PROBLEMS, CAUSES AND CURES - (CONTD.)

1. c. a groove has worn into the mandrel, which also causes the pigtail to stick to the mandrel.

   d. the wire and consequently the pigtail, is too long and gets stuck behind the roller tongue, the pigtail sticking to the mandrel.

2. One wire is not rolled into a pigtail.

   a. the wire is crooked, and cannot be grabbed by the roller tongue.

   b. the wire is either too high or too far out and consequently misses the pressing spring.

3. The Pigtail Is Only Rolled Partly

   a. The roller gets stuck, the toothed segment stalls while the arm rises against the pressure of the spring.

   b. The segment runs too heavily causing the roller not to turn far enough.

4. The Coil is Kinked or Broken

   a. The segment runs too heavily, the roller not returning into its initial position. In this case the coil cannot come from the mandrel and is broken as the mount-holder rises.

   b. The roller is too loose and runs concentrically round the mandrel: the eccentric shaft must be adjusted so that the segment presses against the roller without running too heavily.

   c. The initial position of the roller is incorrect: readjust.

11.3.16 COMMON PROBLEMS, CAUSES AND CURES - (CONTD.)

4. d. The spreader is out of adjustment, one or several hooks being too far out. In this case the coil is pulled along the mandrel as the mount-holder rises, and may get kinked.

11.3.17 MOUNT SHAPING AND COIL TENSIONING

The mount must be finally shaped for correct coil tension and mount geometry. For the most part this operation consists of small changes in lead wire and/or support wires.

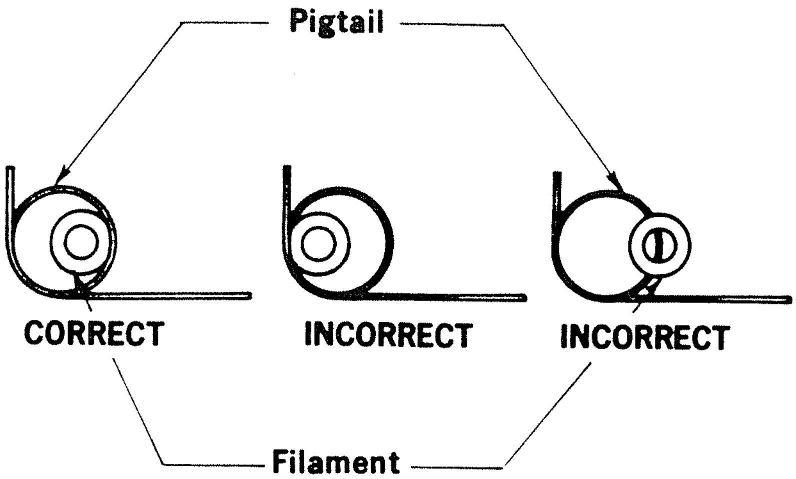
11.3.18 GENERAL RULES FOR FILAMENT TENSION

1. The final efficacy of a coiled coil filament and to a lesser degree, a single coil filament is affected by the amount of tension applied to it during the mounting process. To obtain stable efficacy levels in lamps, it is necessary to keep the degree of tension, from one batch to another, as close as possible.

2. The tension should be such as to hold the filament against the inside edge of the 'pigtail' without distorting the pitch of the filament.

3. When the mount is held horizontal, and each filament support is in turn placed with the plane of its loop at right angles to the floor, the filament in this position must not fall away from the loop.

11.3.18 GENERAL RULES FOR FILAMENT TENSION - (CONTD.)



11.3.19 GETTERING

Getter is applied to the complete mount either by dipping in a phosphorous solution or by application of a ZrAl material to leads near the clamps. Gettering is discussed in detail in Chapter 12.

Figure 11.3.18.1 is a chart of the general rules and practices of mounting.

Figure 11.3.18.2 shows a complete mount of the CC-8 type.

11.3.20 TROUBLE SHOOTING MOUNTING PROBLEMS

The following is a list of common mount problems and probable causes.

MOUNTING:

1.	Cracked studs.	Bad flame adjustment. Getter in pot too high causing liquid to touch stud.
2.	Pigtails shorting in stud.	Bad adjustment of inserting head/heads.
3.	Missing pigtails.	Molybdenum spool empty. Bad adjustment of inserting head. Molybdenum wire tangles on spool.
4.	Hanging filaments.	Vacuum pick-up finger blocked. Setting of vacuum finger faulty. (Check movement and position on filament drum and when delivering filament into leading-in wire hooks) Bad setting of filament trimmers on drum.
5.	Filaments not fed into curling Heads' properly.	Bad positioning of spreader head fingers and adjustment of over-sticker mechanism.
6.	Pigtails miss curling (straight wires)	Faulty curling head. Bad positioning of curling head. Molybdenum too high/too low (Check and adjust at inserting position.
7.	Open pigtail eyes.	Bad adjustment of leaf springs on curling elements.
8.	Uneven pigtail lengths.	Bad positioning of curling elements.
9.	Filament tension faulty.	The mechanism which pushes the leading-in wires forward before curling not adjusted correctly.
10.	Filament in hooks not clamped in correctly.	Bad adjustment of trimmers on drum. Bad adjustment of pick-up fingers.

11.3.20 TROUBLE SHOOTING MOUNTING PROBLEMS - (CONTD.)

MOUNTING:

11.	Filament not gettered.	No phosphorous in getter pot. Level of phosphorus too low in getter pot.
12.	Getter not dry on filament before Transfer from machine.	Bad positioning of heater in relation to filament. Heater not switched on or burnt out. Blower air not turned on or air pipe blocked.
13.	Problems at Unloading.	Exhaust tubes out of line. Stem Machine Heads out of line. Mechanism requires adjustment. Mounted stem conveyor chain requires adjustment.
14.	Broken exhaust stems.	Weak stems (S.M.) Feed-in/take-out mechanism requires adjustment.
15.	Broken rods.	Weak rods (S.M.) Feed-in/take-out mechanisms require adjustment. Heads out of alignment.

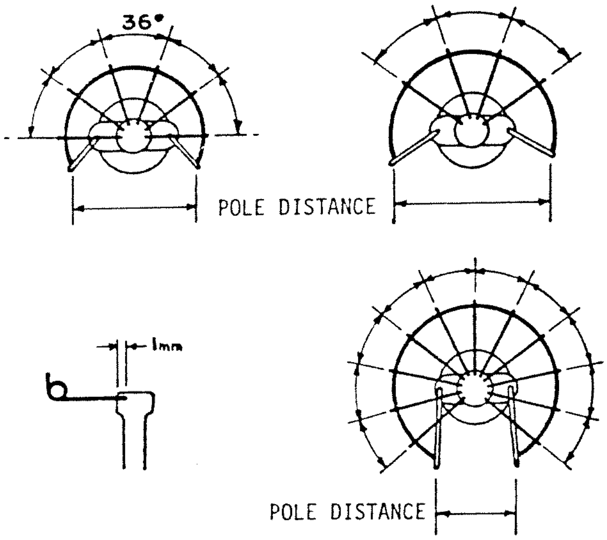
(S.M. = Stem Machine)

FILAMENT MOUNTING

PLATFORM MOUNTS

6 SUPPORTS AT 36° EQUALLY SPACED

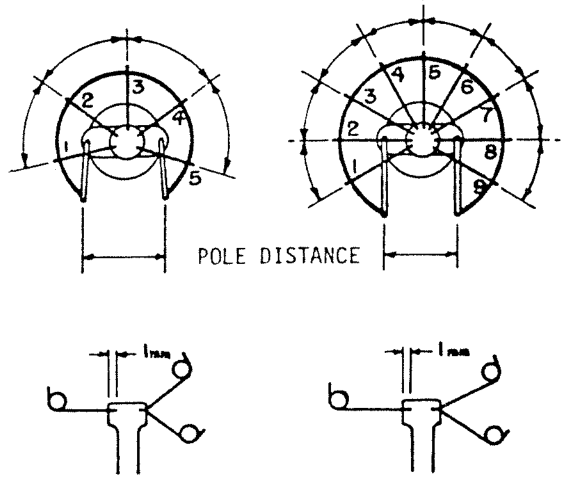
4 SUPPORTS AT 36° EQUALLY SPACED



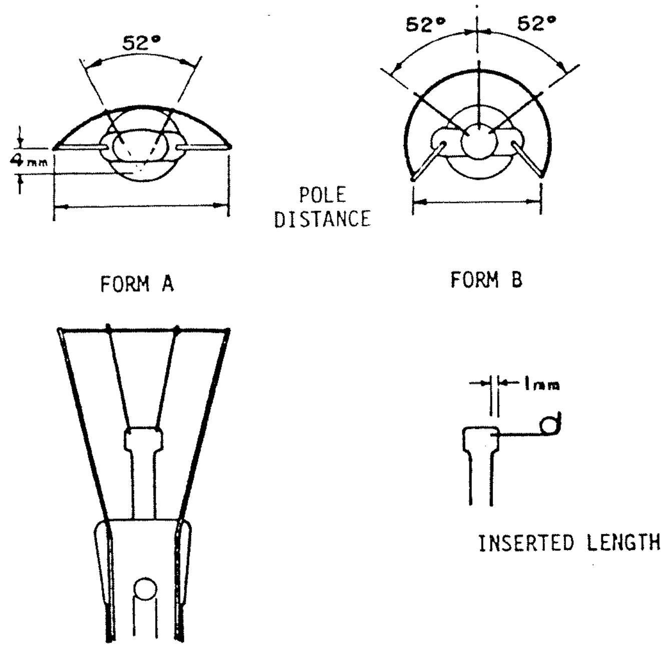
STAGGERED MOUNTS

5 SUPPORTS EQUALLY SPACED AT 54°

9 SUPPORTS EQUALLY SPACE AT 30°



PENDANT MOUNTS



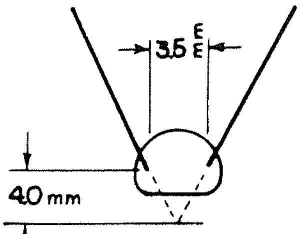
MOUNTED STEM FAULTS

1. WRONG FILAMENT
2. WRONG DIAMETER MOLYBDENUM WIRE
3. UNEVEN MOUNTING (SPACING)
4. MOUNT NOT FLAT
5. MOUNT UNGETTERED
6. FILAMENT BADLY MOUNTED IN HOOKS OF LEADING-IN WIRES
7. MOUNTING TENSION WRONG (TOO LOOSE OR TOO TIGHT)
8. MOLYBDENUM WIRES SHORTING IN STUD
9. CRACKED STUD
10. MOLYBDENUM LOOSE IN STUD
11. STRETCHED OR DISTORTED FILAMENT
12. BADLY ROLLED EYES OF SUPPORTS (OPEN EYES)
13. POLE DISTANCE WRONG

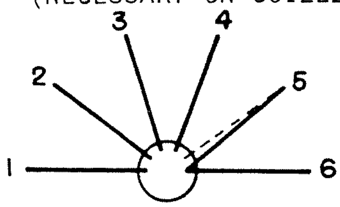
Figure 11.3.19.1a

FILAMENT MOUNTING HAS GREAT EFFECT ON LAMP LIFE AND EFFICIENCY

FILAMENT MOUNTING



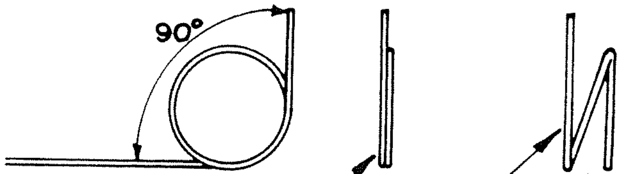
STUD USED FOR PENDANT MOUNTING (FORM A) THIS IS USED IN ORDER TO KEEP MOLYBDENUM SUPPORTS APART IN THE STUD (NECESSARY ON COILED COIL LAMPS)



FAULT

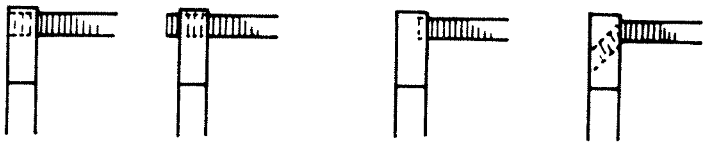
SUPPORT IS WRONGLY POSITIONED (TOUCHING SUPPORT 6 IN THE STUD)

CURLING



CORRECT (Closed eye)

INCORRECT (Open eye) CAUSING SHORTING OUT OF PART OF THE FILAMENT

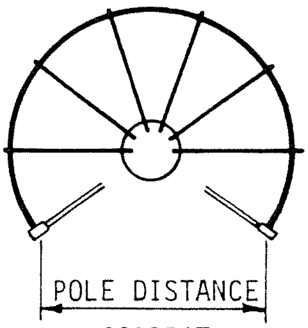


CORRECT

INCORRECT (FILAMENT PROTRUDING THROUGH HOOK)

INCORRECT — FILAMENT NOT SUFFICIENTLY IN HOOK

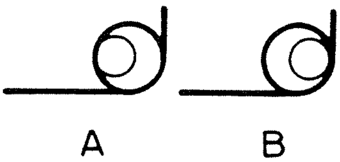
INCORRECT



CORRECT

1. EQUAL SPACING
2. CORRECT POLE DISTANCE
3. POLE WIRES LIE ON FILAMENT CIRCUMFERENCE (CORRECT POLE TWISTING)

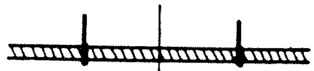
TENSION OF FILAMENT



SINGLE COIL FILAMENTS MUST BE MOUNTED SO THAT THE FILAMENT LIES ON THE INSIDE OF THE EYES OF THE SUPPORTS. (SEE A)

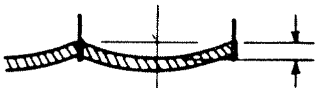
COILED COIL FILAMENTS MUST BE MOUNTED SO THAT THE FILAMENT LIES AT THE BACK OF THE EYES OF THE SUPPORTS. (SEE B)

SAG OF FILAMENT



FILAMENT AFTER MOUNTING

NORMAL SAG FILAMENT IN LAMP AFTER BURNING

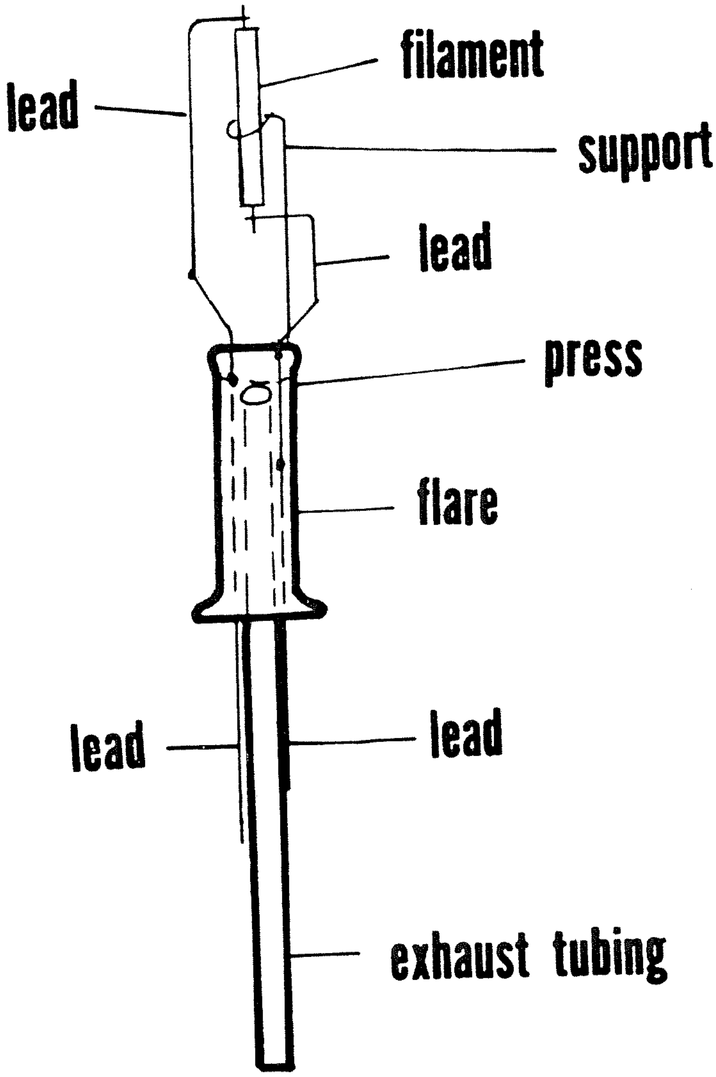


EXCESSIVE SAG FILAMENT IN LAMP AFTER BURNING

SINGLE COIL FILAMENTS

Figure 11.3.19.1b

STANDARD DUAL LAMP



MOUNT
CC-8

Figure 11.3.19.2

11.3.21 REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

1. Equipment Development Training Programs available from GTE Sylvania, Equipment Development Group, Estes Street, Ipswich, MA 01938

   #26 Side Wire Inserters - Introduction

   #27 Side Wire Inserters - Old Sylvania Type

   #28 Side Wire Inserters - New Sylvania Type

   #29 Side Wire Inserters - Miniature Lamp Type

12.0 INCANDESCENT LAMP GETTERS

In lamps and tubes it is desirable either to have as pure a filler gas as possible or as ideal a vacuum as possible. This aim is difficult because, in pumping, a certain amount of gas remains behind; filler gases may not be absolutely pure; and finally, a certain amount of gas always escapes from their parts during the life of the lamp or tube. These gaseous impurities must be made harmless. Getters are used for this purpose.

Getters are thus materials which bind gaseous impurities in lamps and tubes in order to improve their quality. Many factory engineers also think of getters as an "insurance", covering the variations in manufacturing.

The above are very generalized definitions of getters. The term "getters" was supposedly first coined in this country, and originally meant to "get" something undesirable and control it, much in the manner of "scavengers" used in the refining and production of metals.

There is no good, simple definition or precise explanation of the action of all getters or gettering in lamps. In general, the gettering mechanism involves very complicated, and not always completely understood, physical and chemical processes. The researchers and scientific experts themselves disagree on some of the various theoretical considerations involved. Because of this, some people in the lamp business refer to this particular area of lamp making as "witchcraft" - and sometimes they may be right!

12.1 WHY ARE GETTERS NEEDED?

For a lamp to operate efficiently and satisfactorily, its internal atmosphere must be free of certain detrimental impurities - some of which are always present. Moisture, for example, is probably the most serious problem confronting the lamp maker. It is very difficult to eliminate, either in the lamp parts or in the lamp processes. Many other so-called impurities or contaminants are deleterious to lamp quality - these, too, can be introduced either by the lamp parts, the lamp making processes, or a combination of both.

Typical undesirable lamp impurities are the following: water vapor, oxygen, hydrogen, carbon monoxide, and carbon dioxide. Others may manifest themselves, such as hydrocarbons, oxides, mercury vapor, compounds of nitrogen, sulfur, etc. All of these may cause initial blackening, poor lumen maintenance, arcs, early burn-outs, and weak or embrittled filaments.

Most of these impurities do their harm as gases or vapors: oxygen can form volatile oxides and is an essential element for the bulb-blackening water cycle - it can attack and etch the filament in certain **temperature** ranges, causing enhanced erosion of sections of the filament. Hydrogen will reduce oxides and start the water cycle; carbon as an oxidized gas or as a hydrocarbon will form the filament embrittling tungsten-**carbide**; **mercury** vapor can cause arc-outs, as can other unwanted gas impurities.

Early burn-out and short life result from the "abnormal attack" of the hot filament by impurities such as water vapor, oxygen, and

12.1 WHY ARE GETTERS NEEDED? - (CONTD.)

carbonaceous gases. Normally, a filament in a clean atmosphere burns out at its maximum temperature zone, where it is evaporating most rapidly. The filament-attacking impurities usually operate in a selective or cooler critical temperature zone of the filament. This depends a lot on the filament and lamp geometry, lead wire size, support location, etc. Thus a rapid abnormal spot-etching or necking-down takes place and finally causes a localized portion of the filament to burn out.

(These etched spots can be seen visually and dramatically by use of the Filament Spot Tester. This consists of charging condensers on direct current, then suddenly discharging them across the lamp filament under test. The electrical pulse is of such short duration that only the high resistance or necked-down filament portions will light up for an instant. They generally show up as tiny bright spots of light, almost star-like in appearance. They are usually found in or near cooler filament zones, such as the coil ends, in the legs, or at support loops.)

Getters cannot substitute for poor housekeeping and sub-standard lamp making conditions - either in parts, handling, processing, and equipment. This is why it is essential to use clean or fired parts, to store parts properly, to schedule systematic equipment maintenance, and to adhere to standard manufacturing methods. High temperatures at sealing and exhaust for good bakeout is one of the most effective ways of removing water vapor. A good dry and hot flush process, as

12.1 WHY ARE GETTERS NEEDED? - (CONTD.)

used in gas-filled general service lamps, is also very reliable for removing lamp impurities, particularly water vapor.

However, impurities can enter the lamp due to parts and processing; hydrocarbons from machine lubricants or from improperly cleaned tungsten wire; mercury vapor from exhaust pumps; hydrogen from sintered parts and from most metals; carbonaceous gases from glass-ware, from filaments, from leads and supports; water vapor from glass-ware, glass-sealing, tipping-off and from sealing fires; oxygen from oxidized filaments, leads, supports; contaminants from the fill-gas or from the exhaust machines themselves (viz. plumbing, rubbers, valves, manifolds).

Probably the most common yet insidious impurity that plagues all lamps is water vapor. Water vapor is responsible for the so-called water cycle, which manifests itself in excessive, premature blackening with subsequent early burn-out. The water cycle is described thusly: Water vapor present will be decomposed by the hot filament, resulting in the formation of tungsten oxide and atomic hydrogen. The volatile tungsten oxide will distill to the cooler bulb wall, where it will be reduced by the highly reactive atomic hydrogen present there. This reduction process leaves metallic tungsten as bulb blackening, and the resultant hydrogen-oxygen components combine to form water vapor. This, of course, starts the cycle all over again, transporting more and more tungsten to the bulb wall. It is well to emphasize again that this is not a normal bulb blackening condition; this is an abnormal condition that occurs very early in lamp life - and one that ordinarily should not exist.

The water cycle may be shown symbolically as follows:

At the hot filament: $W + H_2O \longrightarrow WO_x + H$

At the bulb wall: $WO_x + H \longrightarrow W + H_2O$

The exact types of tungsten oxides formed are not known, hence we prefer to use the symbol WO_x.

The water cycle exists in both vacuum and gas-filled incandescent lamps. The specific reaction mechanisms differ somewhat because of the gas molecules present in the gas-filled lamps - said molecules colliding with the hydrogen atoms and interfering in their journey towards the bulb wall. However, the end result is essentially the same in all cases.

Gas-filled lamps in general are somewhat more critical in their manufacture. The higher temperature filament, plus the constant convection flow of the fill gas, carrying impurities (if present) around the filament, makes for potentially more detrimental reactions to take place within the lamp. Gas-filled lamp exhaust machinery is generally more subject to possibilities of system contamination, due primarily to flow into, as well as out of, the lamps.

Another reaction basic to lamp making should be described. This is known as the "blue glow" effect, and involves ungettered vacuum filament lamps of generally 30 volt rating and above. After tipping,

12.1 WHY ARE GETTERS NEEDED? - (CONTD.)

the average vacuum incandescent lamp may have a pressure ranging anywhere from 1 to 25 microns. If the lamp is lighted to above a certain minimum filament temperature, a blue glow will develop and fill most or all of the lamp. With sufficient resistance in the circuit, the glow will disappear shortly, with a significant improvement in vacuum.

This so-called blue glow is not to be confused with normal ionization potential of a gas - this vacuum lamp phenomenon will depend greatly on the pressure and reaction nature of the residual gases and the effect of the bulb wall, geometry, etc.

12.2 GETTERING MECHANISMS

Getters operate due to various reaction mechanisms. The mechanisms may be either physical, chemical, electrical, optical, mechanical, or a combination of these.

12.2.1 PHYSICAL - Physical usually refers to the sorption of gases by solids. Sorption can be divided into two major classes: adsorption and absorption. Gas adhering to the surface of a solid as a layer (of one or more molecules thick) is known as **adsorption.** Gas entering the solid's interior, much like that of a gas dissolved in a liquid, is known as absorption. The term occlusion (or occluded gas) is also used in place of the term absorption (or absorbed gas).

The adsorption of gases is much greater for porous materials such as charcoal, silica gel and finely divided or powdered metals and oxides. Adsorption increases as temperature goes down.

12.2.1 PHYSICAL - (CONTD.)

Conversely, absorption (or true solution) of gases in solids such as metals increase, within limits, as temperature goes up.

12.2.2 CHEMICAL - The getter material may react chemically with the residual gas or vapor. Phosphorus pentoxide has a great affinity for water vapor, chemically combining with it to form phosphoric acid, symbolically shown as:

$$P_2O_5 + 3H_2O \longrightarrow 2H_3PO_4$$

Many of the evaporated metals, particularly the readily oxidizable ones such as barium, magnesium, aluminum, and calcium do their gettering chemically. In many cases, the gettering process is very complicated, combining physical and chemical actions. Combination physical-chemical reactions are sometimes generally referred to as chemisorption.

12.2.3 ELECTRICAL - In this case the cleanup is due to electrical fields, such as electrical discharge or bombardment or sputtering. In the previous description of the blue glow process, sorption gettering was effected by the glow discharge.

Electrical bombardment by high voltages, by spark coils, by high frequencies, by sputtering processes, and the like, can, when performed properly, cleanup residual gas impurities. The residual gas atoms or molecules become charged positive ions, and as such, are driven to negative regions, primarily the inner bulb surface. Because of their high velocity, they impinge upon the glass and

12.2.3 ELECTRICAL - (CONTD.)

stick there. For example, the blue glow electrical cleanup causes the residual gases to become adsorbed on the inner bulb surface. Ordinarily by itself, the smooth inner bulb glass surface will not readily adsorb the gaseous impurities.

Incidentally, electrical bombardment may also give reverse effects - i.e., it can cause outgassing of parts, or the evolution of residual gas impurities.

12.2.4 OPTICAL - There are certain classes of so-called getters which, by some complicated mechanism, have the ability of making lamp bulb blackening less opaque. They actually "lighten" the darkening of the bulb wall; said darkening being due to normal tungsten filament evaporation. The exact mechanism - whether it is physical, chemical, mechanical or a combination of mechanisms - is not completely known. Because of its uniqueness as a lamp getter, it is listed separately under the classification of Optical. The cryolites are commonly used for this purpose, and they will be described further.

12.2.5 GASEOUS - This also is a class of so-called getter mechanisms unique to incandescent lamp design. They essentially consist of the noble or inert gases, such as nitrogen, argon, krypton, xenon, or combinations of these. Nitrogen and argon are more commonly used than the others, and make up what are called gas-filled lamps. Nitrogen or argon (or both) become the fill gas.

12.2.5 GASEOUS - (CONTD.)

In effect, the fill gas, usually at about 600 mm pressure in a cold lamp, retards the normal filament evaporation due to its counter pressure. The ability to retard evaporation increases with the gas molecular weight and with the gas pressure. This in turn permits filaments to be operated at higher temperatures and thus greater luminous efficiencies.

One caution: The gas-filled lamps have a greater tendency to arc-out (short circuit) than do the vacuum lamps. The tendency to arc-out increases with the molecular weight of the noble gases due to a decrease in the ionization potential.

By tradition, the above fill gases are called gaseous getters (or getter gases) in the lamp industry.

12.2.6 MECHANICAL - This is another general class of getter devices unique to the lamp business and are purposely designed to improve lamp performance. One example is the use of a small quantity of fine tungsten particles (40-80 mesh), put inside the bulbs of very high wattage (and relatively expensive) special service lamps. After the bulb blackening has reached a certain undesirable amount due to lamp burning, the lamp is removed from its fixture. The tungsten particles are caused to mechanically scrub the blackened inner bulb surface by holding the lamp and swishing the powdered tungsten around inside. After a few minutes, the blackening has been essentially "wiped clean" and the lamp is ready for more burning, with improved light output.

12.2.6 MECHANICAL - (CONTD.)

Another example of mechanically reducing the effect of bulb blackening is the use of collector screens to trap the evaporated tungsten. Solid shields rather than screens or grids are also effective, but, of course, they also shield the light output. The efficacy of the collector screen depends upon its geometry with respect to the filament or mount geometry. It is necessary that the screen be fairly close to the filament, since the screen temperature is also an important design factor. For best results, screens are positioned to be directly above the filament, to be the first surface contacted by gases convective past the filament, picking up vaporizing tungsten on the way. In general, lamp screens are made of nickel wire or perforated sheet nickel - other metals can also be used. As with the tungsten "scouring powder," collector screens are limited to the relatively more-expensive special service lamp types. These devices have been used in projection, searchlight, streetlight, studio, television and related high wattage specialty lamp uses.

12.3.0 GETTER FORMS

Getters and gettering may also be classed as to the general physical form that the getter material is initially in.

12.3.1 COATINGS

These getter materials are generally applied as paints or coatings to lamp parts which during service, remain at fairly high temperatures. They may be sprayed, dipped, or brush painted. This may be phosphorus, cryolite, aluminum, zirconium, tantalum or similar solids or metal powders.

12.3.1 COATINGS - (CONTD.)

The covering of certain sealed-beam lamp mounts by vaporizing aluminum over them in a bell jar would properly come under this class of coating getters. Primarily chemical and physical actions take place with coating getters.

12.3.2 BULK - Bulk refers to pieces of gas-absorbing metals, usually sheets or wires, which are attached to the hot portion of the lamps, such as the leads or supports. In some cases the heating of the bulk getter may be by external means, such as induction heating during processing. In other cases, the hot lamp structure may be made of the getter metal: tantulum supports in quartz heat lamps, titanium anodes in discharge lamps, etc. Aluminum, tantalum, titanium, zirconium, thorium, and barium have been used in lamps as bulk getters. Aluminum inner lead wires got special attention, shortly after World War II, as a gettering means in certain miniature lamps. The action of bulk getters is primarily physical and chemical. The term "bulk" is also used in reference to bulk or volume gettering action, primarily that of physical diffusion and sorption. Here the gettering capability generally depends more on mass, as distinguished from flash getters, where the surface area is of prime importance. The nature of bulk action is very complex and takes place in many forms of getters, such as coatings and flash getters. Bulk action getters tend to get brittle as they operate; thus care in their selection as parts of lamp structure is necessary.

12.3.3 FLASH - Flash gettering generally consists of evaporating certain types of materials - usually alkaline earth metals - by heating during or after the exhaust process. This method is also rarely used in lamps, except for the phosphorus or phosphorus-cryolite getters applied to lamp filaments. Materials for flash gettering are usually quite active chemically, and are relatively volatile. They are commonly used in electron tube manufacture, where they are usually recognizable by the so-called getter mirror, or silvery or dark flash deposit condensed on the tube wall. It is important that this deposit is "aimed" so as not to condense on areas of the tube where electrical damage - arcs, short-circuit, or high leakage may occur.

It is because of the opaque deposit on the bulb wall that electronic tube flash getters are generally unfit for lamp usage. Some typical flash getters are: magnesium, barium, strontium, and calcium, and generally their activation is done by induction heating. Their gettering mechanism is primarily physical and chemical. Their chemical activity is sometimes referred to as corrosion gettering; their physical activity is also referred to as solution gettering. Flash gettering is a very complex and complicated procedure, not readily adaptable to lamps. However, its use in the electron tube industry has advanced to the state of a very sophisticated art as well as science.

12.3.4 VAPOR - Vapor gettering refers to certain getter materials introduced into lamps as gases or vapors. This would include the gaseous getters used as fill gases in lamps. It also includes a class of materials which sublime readily, such as iodine, arsenic, and sulfur. In addition, vapor getters would include the use of added impurities, such as trace amounts of oxygen, carbon, methane, hydrogen, and other materials used because of their general action as scavengers or catalysts, both physical and primarily chemical in their reaction mechanisms.

12.4 DURATION OF GETTERING ACTION

In the preceding discussions, getters have been classified in two general ways: (1) by the general concept of the gettering action, and (2) by the broad classification of the form of getter as introduced in a lamp. There is also another broad concept of the getter applications. There are three categories: initial, continuous, and regenerative gettering.

12.4.1 INITIAL - Initial gettering is that which takes place essentially at one particular moment - after which the main getter action is concluded or diminished. An example of this would be the electrical type of gettering, or the phosphorus flash getter. Many flash getters and some vapor getters do the major portion of their gettering at initial activation.

This is sometimes referred to as Dispersal gettering, where cleanup of residual gases occurs while the getter material is being

12.4.1 INITIAL - (CONTD.)

first dispersed, or volatilized, in the presence of the residual impurities.

12.4.2 CONTINUOUS - This refers to a continuing or perpetual gettering effect, once the lamp is completed. The commonly-used ziroconium lead-wire getter has a continuous action throughout lamp life. Cryolite acts continuously on the bulb wall to reduce the opacity of the lamp blackening. Many coating, bulk, and flash getters are continuous in their action, as are the gaseous getters. Mechanical getters could be classed as continuous-type getters also. This continuous action is in some special cases referred to as Contact gettering. This generally refers to a continuing cleanup even after initial volatilization of the getter material has occurred. Broadly speaking, contact or continuous gettering describes the continuing cleanup of gaseous impurities, as they are continually being envolved and contacting the lamp getter during the life of the lamp.

12.5 REGENERATIVE - A regenerative lamp getter is a special case of a continuous class of getters. These are getters which are capable of depositing the evaporated tungsten back on the filament from whence it originally came. Most of these regenerative mechanisms are quite complex, and primarily have made use of the halogens. The iodine getter gas used in quartz tubular filament lamps is an outstanding use of the regenerative cycle. The use of corrosive iodine

12.5 REGENERATIVE - (CONTD.)

requires special non-corrosive processing equipment, as well as the use of lamp parts that are unattacked by the iodine.

The amount of iodine introduced as a vapor is very small, accounting for only a few mm of partial pressure.

The iodine cycle prevents blackening and re-deposits tungsten on the filament as follows:

Tungsten evaporates on the bulb wall. Atomic iodine formed by the hot filament reacts with the bulb wall tungsten to form volatile tungsten iodine. The tungsten iodine diffuses to the filament where it is decomposed, depositing tungsten back on the filament and producing atomic iodine to repeat the iodine cycle.

The reaction is given as:

At the bulb wall: $W + 2I \longrightarrow WI_2$

At the hot filament: $WI_2 \longrightarrow W + 2I$

12.6 COMMONLY USED LAMP GETTERS

12.6.1 PHOSPHORUS

Red phosphorus getter is probably the oldest and most widely-used getter material in the lamp business. It is exceptionally good for gas residuals such as O_2, H_2, CO, CO_2, H_2, and H_2O. Its gettering action, depending on its use, may be chemical, physical, or both. It can be applied as a coating or as a flash type of getter. It is generally more effective as an initial type getter, rather than continuous. However, when used with electrical

12.6.1 PHOSPHORUS - (CONTD.)

activation, such as in multiple Christmas lamps, it shows signs of continuous activity.

It may be applied to coils, lead tips, beads, or supports. It is generally applied to filaments, either by brush painting, hand-or mount-machine dipping, or by spraying, using fountain, whirlwind, or hand methods.

Its complex gettering mechanism is not completely understood, although there are various theories explaining its overall action. Many researchers subscribe to the explanation that the presence of white phosphorus (usually found as trace amounts in red phosphorus) is important to the gettering capability.

Relatively small amounts of phosphorus by itself is most commonly used on the filaments of standard voltage gas-filled lamps. Phosphorus getters generally use methanol as a vehicle for dipping or for painting. For spray-gettered coils (and in some instances, for brush or dip gettering), the phosphorus is generally mixed with amyl acetate as the vehicle, plus a nitrocellulose binder to provide adherence.

Phosphorus getters can be easily damaged during lamp processing. Overheating can burn the getter and render it ineffective. Careless storage of getter or gettered mounts can attract moisture and reduce the effectiveness. Phosphoric acid formed by ambient moisture can chemically attack the filaments of such carelessly-stored gettered mounts.

12.6.1 PHOSPHORUS - (CONTD.)

Lumps of phosphorus on lamp parts should be avoided. Getter lumps at support loops, lead clamps, coils and on coil legs can cause poor gettering and in many cases, filament burn-out.

12.6.2 CRYOLITE

Cryolite as used today consists of the natural cryolite, sodium aluminum fluoride - as well as the synthetic compound, sodium iron fluoride. These are also known as double fluorides, compounds which over the years have been intensively investigated regarding their lamp gettering ability. Like many other complicated gettering processes, the action of double fluorides is not completely understood. It is known that most of the double fluorides, having an alkali and metallic fluoride in combination, have this gettering ability. Of the alkalies, sodium and potassium give the best results. The trivalent metals, such as aluminum and iron, also give superior gettering action.

Cryolite is generally used in most vacuum lamps, usually in combination with phosphorus. It is applied the same as phosphorus (coils, leads), and requires similar care and precautions. Cryolite's action in vacuum lamps is classed as an optical getter - that of vaporizing fairly evenly on the inner bulb surface and causing normal filament evaporation to appear less opaque. Thus it acts as a continuous getter for improving lumen maintenance during lamp life.

Cryolite's presence in standard or higher-voltage gas-filled lamps cause arc-outs. However, it has been successfully used, with

12.6.2 CRYOLITE - (CONTD.)

phosphorus, in some low-voltage gas-filled miniature lamps (e.g., Lamp #55) on the filament and lead tips. Here its action is considered chemical, and is given by the following equation for chemically taking up oxygen from water vapor:

$$2Na_3AlF_6 + 6H_2O \longrightarrow Al_2O_3 + 3Na_2O + 12HF$$

When used in the low-voltage gas-filled miniature lamps, generally a small amount of grey-white bulb discoloration will appear as a cloudy streak due to the gas stream effect.

12.6.3 PHOSPHORUS-CRYOLITE

Many combinations of phosphorus-cryolite getters are in use today. These are designed with different ratios of phosphorus to cryolite, as well as different vehicle and solids ratios. The difference depends on the different lamp types and conditions, as well as the methods of application. The varying degrees of phosphorus particle sizes and milling times are also designed into the different getter formulations.

Where initial vacuum cleanup is most important, the ratio of phosphorus to cryolite is generally high - in contrast to where improved lumen maintenance is important, then the proportion of cryolite to phosphorus should be correspondingly increased.

Phosphorus with cryolite is almost universally used in many miniature lamp applications. This combination is automatically applied to the lead tips of many small-bulb gas or vacuum low-

12.6.3 PHOSPHORUS - CRYOLITE - (CONTD.)

voltage lamps. If applied to the filament of these small-bulb lamps, annoying bulb discoloration may take place.

Phosphorus plus cryolite applied to the filament of higher voltage vacuum lamps (approx. 30 volts and up) does an excellent gettering job. Here advantage is taken of the "blue glow" effect. The presence of the filament getter causes the blue glow ionization to take place much faster and more briskly. Within a few seconds, with the proper voltage and temperature relationships, the lamp vacuum is improved from many microns down to less than one micron of pressure. For optimum results, it is important that the lamp bulbs be relatively cool during the "flash-out" process.

The phosphorus does most of the initial gettering at flash-out, while the cryolite instantly evaporates to the bulb wall where it acts as a continuous getter for the bulb blackening. If too little getter is used, the blue glow effect will hang on too long; final vacuum will still be "soft." This could cause arc-out when the lamps are then lighted later in an unballasted position. Too much getter results in a noticeably yellowish bulb discoloration. The cryolite tends to add an irridescence to the yellow discoloration. The very effective gettering results of phosphorus and cryolite when used with the blue glow effect is considered to be due to both chemical and physical action. Chemically, P_2O_5 may be formed by residual oxygen. This in turn will getter water vapor. Physically, phosphorus is also considered to be most effective in adsorbing the positive ion gas dissociation products, due to the glow discharge, at the lamp bulb wall.

12.6.3 PHOSPHORUS - CRYOLITE - (CONTD.)

The use of phosphorus or phosphorus-cryolite getters applied to the lead tips of small vacuum lamps, such as flashlight lamps, is quite common. However, in many cases of this kind, the net accomplishment is somewhat borderline. One of the reasons for this is due to the fact that the lead tips in these particular lamp types do not operate hot enough. Repeated tests will show some gettering advantages, although in many cases very slight.

12.6.4 ALUMINUM

Aluminum as a continuous-type getter is also quite commonly used in lamp making today. Its main attribute is that of absorbing oxygen, especially if subjected to relatively high temperatures. Thus, aluminum as a getter is only effective when used in "hot" lamps, and here it acts as a continuous getter for inhibiting the water cycle.

Aluminum is applied as a paint on those lamp parts which operate hot: lead tips, shield, supports, etc. As a paint, consisting of finely divided aluminum flakes in a binder, it must be kept off the filament. Otherwise burn-outs, or brittle filaments due to tungsten-aluminum reactions, may occur.

The hotter the aluminum, the better it works in most lamps. Of course, if too hot it can vaporize and cause bulb discoloration. Thus, when applied to the inner leads or supports, it should be put on as close to the filament as possible - at the lead tips, etc. Aluminum is primarily used in gas-filled lamps, and particularly

12.6.4 ALUMINUM - (CONTD.)

placed where it can be readily heated by the filament. However, it is considered a relatively poor getter for most miniature lamps.

In a few rare cases, it has been applied by vacuum vapor deposition techniques on the entire lamp mount. Then at light up, the thin filament coating of aluminum vaporizes off. This plus the lead coating, act as the lamp gettering mechanism. (Aluminum does its most effective gettering when flashed, as in certain electronic tubes.)

Some miniature lamps make use of aluminum getter with cryolite added. Besides its use as a coating or flash getter, aluminum has been somewhat effective as a bulk getter. For a time during periods of nickel shortages, some slight advantage as a combination aluminum inner lead and getter was achieved in certain lamp types.

As with other getters, the importance of completely burning out and decomposing the aluminum paint binder is essential during lamp making. Otherwise, residual carbonaceous impurities can cause filament embrittlement.

12.6.5 ZIRCONIUM

Zirconium as a continuous-type coating getter is widely used on many types of lamps. It has the ability for gettering O_2, H_2, CO, CO_2 and N_2, being particularly effective with O_2 and H_2. Its gettering ability ranges from temperatures of about 25° to 800°C. However, while most effective for a given gas at one temperature, it will liberate it at some higher temperature. Thus, the use of zonal

12.6.5 ZIRCONIUM - (CONTD.)

painting - covering a lead wire - from lead tip to near the stem press - is very effective. In this way the zirconium is heated throughout a whole range of lead wire temperature gradients - selectively absorbing the different gas impurities at the different temperature zones of the lead coating.

Like aluminum, it is applied to various metal lamp parts except the filament. However, when first used as a metallic powder and binder lamp getter paint some twenty years ago, in miniature lamps, its adherence was very poor. It would easily break up and flake off the inner lead wires. When a small proportion of aluminum flakes were added to the paint, its adherence immediately improved. Today, all zirconium paint getters have some aluminum added primarily for improved coating adherence.

As regards to its gettering ability, zirconium is considerably more effective than aluminum. Like aluminum, however, zirconium is primarily used in gas-filled lamps. It has been found effective in certain vacuum lamps - especially those vacuum lamps subject to very hot environments, such as range oven lamps and the like. Zirconium lead wire getter has also been used in conjunction with the use of phosphorus (or phosphorus-cryolite) filament getters in the same lamp. These cases are not too common and require special conditions in order to derive any benefits.

One additional advantage to zirconium (or aluminum) lead wire getter paints is the use of these materials for covering badly oxidized leads. Heavy oxides are bad in most lamps, since they

12.6.5 ZIRCONIUM - (CONTD.)

volatilize during lamp burning; then tend to produce water cycle or filament etching. It has been shown that covering the oxidized inner lead wire areas with the metallic getter paint greatly minimizes their (the oxides) potential hazards.

The same caution and care regarding aluminum getters also applies to zirconium getters.

Zirconium getter is also used in Europe as a bulk getter. Coils of zirconium wire are screwed over the inner lead wires of certain high wattage projection lamps. A combination zirconium hydride-aluminum getter (M getter) is also used by Philips. The German Osram Company uses some zirconium in solution with phosphorus in their cataphoretic method of applying getter coatings to lamp filaments.

When the zirconium (or aluminum) getters are most effectively doing their job is usually indicated by a blackening of the silvery paint on the particular lamp parts that were coated. This is generally a good indicator and something to look for after the lamps have at least been seasoned.

12.6.6 TANTALUM

Tantalum finds some slight use as a bulk metal getter in a few lamp types. It has been found effective as a lamp part (e.g. supports) in areas of high temperature. There have been some cases of its use as a coating, made up essentially in the fine metal powder form. It finds effective use as support material in tubular

12.6.6 TANTALUM - (CONTD.)

quartz heat lamps. (It cannot be used in iodine quartz lamps since it reacts with the iodine.) Oxygen and nitrogen are gettered to some extent. Its use is primarily as a continuous-type getter. Tantalum finds much use in the electronic tube industry as a getter by itself, or in combination with other metals as a getter material.

12.6.7 TITANIUM

Like tantalum, titanium metal finds some use as a bulk getter in a few special lamps. Like many of the other active metals, it getters oxygen, hydrogen, and nitrogen. Its use is primarily as a continuous-type getter.

One problem in the use of bulk metal getters is that many of them should be carefully and properly vacuum heated in order to effectively out-gas them. For example, for tantalum, an outgassing temperature as high as 2000^{o}C is necessary.

INCANDESCENT LAMP GETTERS

Figure 12.6.5.1 shows the difference in gettering efficiency of activated vs. not activated Zr getter.

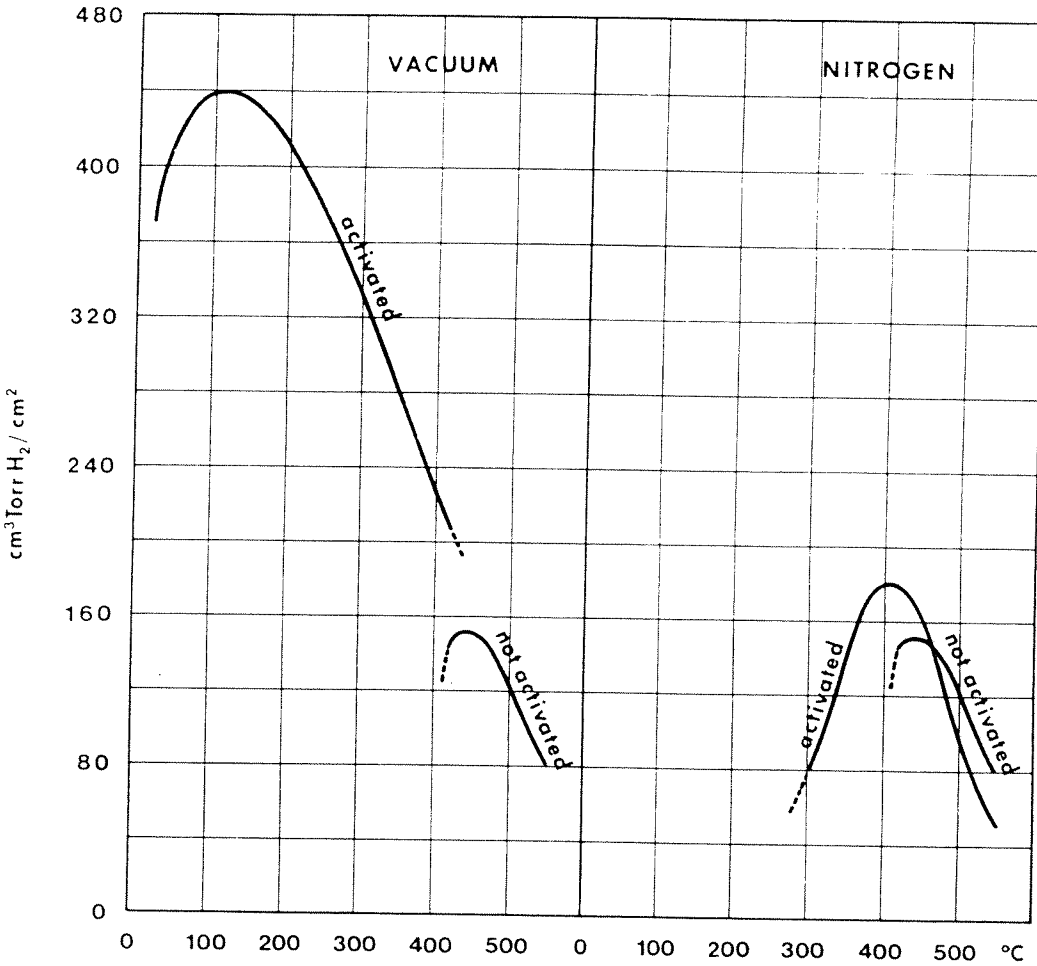


FIGURE 7 Total H_2 quantity sorbed as a function of temperature for Zirconium getters under four experimental conditions.

FIGURE 12.6.5.1

12.6.8 NITROGEN GETTERING BY TANTALUM AND ZIRCONIUM

One difficulty in working with getters like tantalum or zirconium is the fact that they also getter nitrogen at some particular temperature range. In other words, as was previously indicated, some getters will work for different gases at different temperatures. In many cases, we do not want to getter nitrogen, for example, but wish to use the bulk getter primarily, say, for oxygen. Therefore, with a knowledge of the getter's temperature - gas gettering selectivity, and if we know the operating temperatures of the various lamp parts - leads, supports, shields - then the type of gettering we desire can be properly designed and controlled.

The Table below gives some figures concerning the absorption capacity of the Zr getter.

	CO	O_2	N_2	H_2
25°C	16	50	4	30
100°C	20	70	7	20
200°C	26	150	11	10
300°C	34	400	19	4

In the figures for H_2 it should be noted that they apply to an equilibrium pressure of 10 microns of H_2 above the getter. As this equilibrium pressure at a given H_2 concentration in the getter increases with temperature, the permissible concentration at constant equilibrium pressure is reduced with rising temperature.

That is to say, the gettering capacity decreases with increasing temperature, although the rate at which an unsaturated getter will absorb hydrogen increases with temperature.

Finally, the temperatures at which some getters begin to absorb gas perceptibly are shown in the following Table. These values were

12.6.8 NITROGEN GETTERING BY TANTALUM AND ZIRCONIUM - (CONTD.)

measured by taking previously activated getters and, after adding gas, slowly allowing the temperature to rise. In the case of most of the getters a slight getter effect occurred as soon as the gas was added.

	O_2	N_2	H_2	H_2O
Zr-powder	150	550	-	300 - 500
Ti-powder	100	400	-	160 - 300
Zr-plate	300	750	600 - >800	670 - ?
Ta-plate	250	900	400 - 600	400 - 600
Nb-plate	<250	-	330 - 600	-

12.6.9 ZIRCONIUM - ALUMINUM GETTERS

In certain applications of gas-filled lamps, it has been found that a mixture of zirconium and aluminum is more effective than aluminum alone in preventing early blackening. Zirconium is known to getter oxygen, nitrogen, hydrogen, carbon monoxide, carbon dioxide and water vapor. It will getter nitrogen between 800°C and 1600°C and should therefore not be placed on parts of gas-filled lamps of argon and nitrogen where the operating temperature of the gettered part is within this range. Otherwise the getter would become saturated with an excess of nitrogen, become inactive and not bind the harmful gases. This mixture type getter is handled in much the same manner as aluminum.

The getter (20% Zirconium - 80% aluminum) has been tried in special high wattage PAR lamps but has not been found to be as

12.6.9 ZIRCONIUM - ALUMINUM GETTERS - (CONTD.)

adaptable to PAR lamp processing and application as the all-aluminum getter currently being used.

Zirconium-aluminum getters are intended for lead wire application only; they are not effective unless there is sufficient heat to promote the necessary reactions. If allowed to come into direct contact with the hot portion of the filament, the getter will vaporize and may cause burn-out or short life lamps, and the vaporized getter will deposit on the bulb wall and leave a gray discoloration. Getter should be applied as high as possible on the mount.

12.6.10 PHOSPHOROUS PENTANITRIDE (P_3N_5)

Improved gettering of electric incandescent lamps is claimed by flashing therein a getter consisting of pure crystalline phosphorous pentanitride (P_3N_5). It is preferably used alone in gas-filled lamps but may be mixed with an oxidizing agent, and/or with cryolite in vacuum lamps.

The object is to provide a getter material which is fast acting and which is stable so as to be resistant to water vapor and to deterioration at the relatively high temperature involved in lamp making. Another object is to more efficiently effect the clean up and removal of residual atmospheric gases in incandescent lamps, especially those of the gas-filled type, although it is also highly useful in those of the vacuum type.

Pure crystalline phosphorous pentanitride (P_3N_5) provides superior gettering action. It is resistant to deleterious reaction

12.6.10 PHOSPHOROUS PENTANITRIDE (P_3N_5) - (CONTD.)

with water vapor and other atmospheric gases at temperatures applied to the lamp during the sealing-in and exhaust operations, and it may be subsequently thermally decomposed, presumably into its component elements phosphorous and nitrogen, by heating to more elevated temperatures of approximately 1000°C. When P_3N_5 is thermally decomposed, the phosphorous so produced is nascent and extremely active. This white phosphorous component is extremely effective and fast-acting in clean up of oxygen and water vapor, and some of its deposits on the interior lamp parts including the bulb walls enables it to persist in its clean up action during lamp life. In gas-filled lamps it is presently preferred that the pure crystalline P_3N_5 be used alone as the getter composition, but very successful results have also been obtained by admixing it with a quantity of oxidizing agent. In vacuum lamps, the P_3N_5 (with or without oxidizing agent) is preferably mixed with cryolite as is conventional with red phosphorous getter. In this case it may also be desirable to add red phosphorous to maintain a low vacuum; or stated differently, it may be desirable to replace some of the red phosphorous with P_3N_5 in the conventional getter for vacuum lamps. The amorphous form of phosphorous pentanitride has been found to be unsatisfactory. Crystalline P_3N_5 is not a commercial product. It is preferably prepared by the reaction of P_2S_5 with ammonia.

The following process is used to prepare a P_3N_5 getter suspension.

12.6.10.1 MATERIALS

400 g	phosphorous nitride
3,65 l	methyl-isobutyl ketone 99% tech. grade
470 ml	nitrocellulose sol. 4,35% in methyl-isobutyl ketone

Yield (for calculations): 4336 ml

12.6.10.2 APPARATUS REQUIRED

roller table

5-litre ball mill, 60 revs/minute, holding 3kg pebbles of $\frac{3}{4}$" dia.

2-litre graduated jar

1-litre graduated jar

10-litre polythene bottle

6 one-litre glass bottles with screw caps, code no. 2822 800 07448 sieve, phosphor-bronze gauze of 0,042 mm mesh width, code no. 0322 103 01002

balance(precision 5g)

12.6.10.3 MANUFACTURE

1. Transfer the phosphorous nitride along with the nitrocellulose solution and 1150 ml methyl-isobutyl ketone to the ball mill and run it for 24 hours.
2. Transfer the suspension to the polythene bottle.
3. Rinse the mill with the remaining 2500 ml methyl-isobutyl ketone and transfer the wash also to the bottle.

12.6.10.3 MANUFACTURE - (CONTD.)

4. Properly mix the liquid in the bottle by shaking.
5. Transfer the suspension through the sieve to the glass bottles, about 750ml/each.
6. Have a sample (40 ml in a 50 ml bottle) tested by Q.D.L. Maarheeze. Test requirements:
   solids content: 11,0 ± 0,5%

Yield

about 4300 ml

Use

as a getter in incandescent lamps.

12.6.10.4 STORAGE

In well-closed bottles.

Label must show: name, code and batch number.

The symbol for fire hazards should be applied near the label.

12.6.10.5 COMPOSITION IN WEIGHT %

phosphorous nitride	10,24%
methyl-isobutyl ketone	79,52%
nitrocellulose solution	10,24%

12.7 GENERAL GETTER DESIGN

There is no hard and fast specific procedure for the design and formulation of lamp getters. Primarily, however, the following lamp parameters play a part, to varying degrees of importance, when considering getter design:

12.7 GENERAL GETTER DESIGN - (CONTD.)

current	ratio bulb surface area/lamp wattage
voltage	inner lead temperatures
wattage	factory seasonal conditions (humidity,etc.)
lamp life	lamp application and environment
coil shape	lamp quality and reliability required
mount shape	process heating, time, temperature
bulb shape	housekeeping, lamp and parts storage
bulb size	supports, shields, other
lumen maintenance	bulb proximity to coil
lamp efficiency	filament wire size
exhaust schedule	coil or coil-coil
machine speeds	gas or vacuum
bulb temperatures	type of fill gas
manufacturing processes	lead-tip spacing
machine maintenance	inner-lead size

Getters are somewhat akin to soldering fluxes - they have to be designed and used according to various empirical conditions and process environments.

When gettered lamps have been operating satisfactorily for long periods of time, and then apparently become troublesome, showing erratic life, early blackening, and the like, it does not necessarily indicate the need for a getter redesign. In cases like this, it is wiser and proper to first check any change or lack of care in handling of lamp parts or manufacturing processes. Process controls should be adequately checked, as well as parts and unfinished lamp storage. Seasonal effects (e.g. humidity) should be considered, and, of course, the getter in use at the time should be carefully investigated and tested; or a fresh lot of getter should be used.

12.7 GENERAL GETTER DESIGN - (CONTD.)

After all these immediate past-history checks have been carefully appraised, then, of course, it is conceivable that a change or redesign of getter may be appropriate.

Sometimes in cases like this, either the location of the getter in the lamp, or the method of getter application might be changed.

12.8 HANDLING OF GETTER MATERIALS

12.8.1 ZIRCONIUM GETTERS

1. The major hazard of zirconium is fire and explosion. It has a comparatively low ignition temperature, is highly flammable in the dry state, and burns with an intensely brilliant flame, which cannot be extinguished with water or CO_2. The powder will produce an explosive mixture with oxidizing agents such as barium nitrate or potassim chlorate.

2. Ignition temperatures of the dry powder are reported to be from 150 to 160C according to the grade. The dry powder is ignitable at low temperatures by heat, static electricity, or simple friction. Zirconium powder, wet with water, is much safer to handle than dry zirconium powder because it is more difficult to ignite. Once ignited, however, the wet powder will burn more violently than the dry powder. The powder containing about five to ten percent of water is stated to be the most dangerous.

12.8.2 PHOSPHOROUS

1. Red Phosphorous is a stable and harmless element when properly handled.

2. Phosphorous can be ignited by friction and/or shock.

   a. Avoid all fumes from burning phosphorous.

   b. Burning phosphorous can be extinguished when wetted with water but may ignite if allowed to dry out again.

   c. All wetted material shall be washed into the sewerage system (if EPA Regulations Permit) and not disposed of in waste receptacles.

   d. Avoid the contact of phosphorous with any metallic object and use spark-proof equipment in handling dry material.

      1. Do not use metallic spatulas - etc.

      2. Avoid all friction with dry material.

   e. Dispose of all spilled material and wipe up with a cloth that has been wetted with water.

      1. Wash wetted material from cloth into the sewerage system (if EPA Regulations Permit).

12.8.3 GETTER SOLVENTS

Materials other than phosphorous used in the manufacture of getter, such as alcohol, amyl acetate and ether are highly flammable and explosive.

1. KEEP GETTERS AWAY FROM FIRES.

2. Alcohol used on the manufacturing floor shall be kept in safety containers and when not in use, kept covered and away from sealex fires.

12.9 HANDLING DURING LAMP MANUFACTURE

1. Keep all getter bottles and equipment for handling them clean.
2. Store all getter in steel fire-proof cabinets.
3. The following checks for leaking bottles are to be made:
   a. Before leaving Chemical Production Laboratory.
   b. All opened bottles when recapped before agitation.
   c. Capped gallon bottles made up from concentrated getter solution before agitation.
4. Return all empty bottles to the Chemical Production Laboratory as soon as possible and avoid having too many empty getter bottles on hand.
5. All spilled getter is to be cleaned up before it can get dry, wiping up small amounts with a cloth wetted with water.
   a. Large amounts should be soaked up, omitting any rubbing.
   b. Clean spot with wetted cloths and thoroughly wash all cloths used for phosphorous getter until they are free from any amount of getter material.
   c. Any cloths which have been in contact with Zirconium should be disposed of while wet, if possible, in a separate container.
6. All getter should be thoroughly washed from broken getter bottles, pieces of bottles and parts of equipment.
7. All overage or unused getter shall be returned to the Chemical Production Lab, for disposal.

12.9 HANDLING DURING LAMP MANUFACTURING - (CONTD.)

8. The amount of getter allowed on the agitation mills at one time is limited to one day's production and greater amounts are to be avoided.

9. Keep getters away from fires as material used in getter manufacture is highly flammable and explosive.

12.10 CARE AND USE OF GETTERS

All bottles containing getter should be kept tightly stoppered to prevent evaporation, chemical changes, and absorption of moisture and other impurities.

BOTTLES CONTAINING GETTER SHOULD BE KEPT AWAY FROM DIRECT SUN-LIGHT. THIS MAY HAVE SOME DETERIORATING EFFECTS ON THE GETTER AND, WORSE YET, IT MAY IGNITE PHOSPHOROUS OR ZIRCONIUM PRESENT, THROUGH LENS EFFECTS IN THE GLASS. Empty bottles should be recapped to prevent the residues from drying and caking, and they should be generally treated as a potential fire hazard.

It is very important that, while getters are in use and before use, they be kept well-agitated, to insure uniformity of mixture, and complete suspension of all solids. Zirconium is particularly heavy and difficult to keep in suspension.

Getters, gettered mounts, or gettered filaments, should not be kept where they will be exposed to fumes from other chemicals. Such fumes are likely to combine with the getter ingredients and form new compounds.

12.10 CARE AND USE OF GETTERS - (CONTD.)

Only fresh getters should be used. When used in open containers on a machine, getters should be disposed of and replaced with fresh getter at specified intervals.

Spray getters are sometimes contaminated by water and oil which come from the high pressure air line. A suitable filter placed in the line will help to avoid this trouble.

Gettering operations should be kept as close to the lamp sealing operation as possible.

Getters are easily affected by moisture, especially when the moisture is accompanied with heat. Those factories which are in localities where humidity is high should watch for trouble from this source. If phosphorous is present in the getter, it oxidizes and combines with moisture from the air to form phosphoric acid. This not only nullifies the purpose of the phosphorous, but the phosphoric acid attacks the filament and etches it. The net effects are likely to be hot spots, weak or brittle filaments, burnouts, low efficiency and short life.

Filament gettering should be smooth and uniform. Beading retards vaporization of the getter at flashing, and results in a temporary fusion of the getter masses. While in a state of fusion, the getter violently attacks the filament and etches it, causing hot spots, weak filaments, and short life.

When filament gettering is used, the amount of getter called for in the Lamp Construction Data should be closely adhered to. This is particularly important when dealing with vacuum type lamps. Too

12.10 CARE AND USE OF GETTERS - (CONTD.)

little getter provides insufficient clean-up, and this results in gassy lamps, burnouts, short life, and poor efficiency; too much getter causes weak filaments and discolored bulbs.

Recommended getter checks should be made frequently enough to insure compliance with specifications.

Getters which contain zirconium or aluminum must be kept confined to the lead wires or other parts for which they are intended. Extreme care must be taken to prevent spattering onto the hot part of the filament.

In general, any surface or material properly and completely denuded of gas is capable of adsorbing (or absorbing) residual gases. In other words, many different lamp parts may act as getters - filament, bulb, leads, and the like.

One device which can on certain occasions be used effectively is that of flashing an oxidized filament. The tungsten oxide volatilizes off at light-up and tends to "harden" the vacuum. This can be useful in tiny vacuum lamps. However, too much filament oxide can discolor the bulb at initial light up, adversely affect the lamp atmosphere, or significantly affect the filament electrical ratings. In some cases, the use of lighted filament exhaust is helpful in driving out gaseous residuals.

12.11 GETTER APPLICATION TO MOUNT

It is important to understand that the solid components of getter are not in solution, but in suspension. The solids settle very

12.11 GETTER APPLICATION TO MOUNT - (CONTD.)

rapidly to the bottom of the container when the contents are not being agitated.

There are several methods of applying getter:

12.11.1 SPRAY METHOD

This consists of spray coating coils before mounting. The type of getter is specified for each coil type, along with a percent range as for example 7 - 9%. This means that the amount of getter applied to the coil will be 7 to 9% of the weight of the coil. The process consists of passing a spray bath of getter and purified air upwards through a quantity of coils. The coils are fluffed up by the air stream and agitated sufficiently so that a uniform coating is applied to all of the coils. The coils are removed at intervals and weighed until the proper weight is obtained.

Because of its ability to produce a uniform coating, and to control accurately the amount of getter applied, the spray method is considered superior to the dip method. However, spray gettered coils are not feasible for automount handling. Therefore, the dip method has become standard for automount types.

12.11.2 DIP GETTERING

This consists simply of holding the mount with coil down and submerging the coil in getter. As mentioned earlier, the getter must be kept agitated. A common automount device consists of a stationary pot with a moving cup which lowers into the pot, then lifts to dunk

12.11.2 DIP GETTERING - (CONTD.)

the mount as it indexes into position over it. The motion of the cup keeps the getter agitated.

12.11.3 PAINT GETTERING

Zirconium getter is placed on the specified location, most commonly the lead wires by means of a dauber. The dauber can be a piece of wire, a spring or any other form that will pick up the getter solution and deposit it on the lead. There are several automatic devices for this operation. The major requirements are as follows:

1. The Zr must be kept in suspension. The Zr is the largest particle and the heaviest in the getter solution. To keep the Zr in suspension, the getter solution must be agitated vigorously continually. Another factor is the viscosity of the solution. The solution thickens due to evaporation of the Amyl solvent. Additional solvent must be added periodically to maintain the desired viscosity of the getter solution. If too much solvent is added too fast, the solution will become too thin and only Al will be deposited. It is only the Zr that is of any value in gettering. The Al has only a slight gettering ability and is added to aid adherance to leads and also as a fire retardant in getter manufacturing. Of all the devices in use, the one most effective in maintaining the Zr mixture and suspension is the peristaltic pump-bubbler type. This device is a piece of Nordel rubber tubing (E.I. Dupont), a 4 lobe cam, a backup shoe and a 10 rpm motor. The device is a continuous bubbler.

12.11.3 PAINT GETTERING - (CONTD.)

The getter solution bubbles out one end of the tube into a funnel which is attached to the other end of the rubber tubing. The continued feed and re-cycling results in slow evaporation of the solvent and no settling of the Zr. When solvent is added, it is added to the funnel and is mixed thoroughly before it reaches the bubbler. The dauber picks up getter material directly from the bubbler to deposit on the leads. The flowing action of bubbler helps to prevent build up of direct getter material on the dauber. Note: Nordel rubber or its equal is required because Amyl acetate will attack most rubber compounds and cause swelling of the tubing and jamming of the pump.

2. The getter material must be placed as close to the clamp as possible without getting any getter material on the filament. Pre-heating the leads will aid in fixing the location of the getter especially when the getter is on the thin side. If the getter is too thick, a gob will be deposited on leads which will fall off and become an ineffective and a possible source of lamp failure if the getter comes in contact with the hot filament.

12.12 COMMON GETTER PROBLEMS

12.12.1 BURNED GETTER

It is important to avoid burning the getter at sealing in. Careful adjustment of sealex flood and etching fires is necessary. Burning or even slight scorching of getter results in contamination of the filament. Visible indication is uneven spacing of turns in

12.12.1 BURNED GETTER - (CONTD.)

the flashed coil, with some turns very close together or touching. Usually examination of the mount in an unflashed lamp will show evidence of burning by a change in color of the filament from the original red-brown color. Sometimes this change is so slight as to be barely perceptible.

Radiant type burners may result in excessive heating of the filament because the radiated heat is absorbed much more readily by metal than by the glass bulb.

12.12.2 BEADING

Getter may collect in heavily concentrated spots along the coil. This presents problems similar to those caused by burned getter. It may be avoided by shaking the mount in some manner to remove excess getter immediately after dipping. In fine, close-pitch coils, the use of a getter with low binder content is helpful in preventing the getter from caking between the turns.

12.12.3 UNEVEN GETTERING

This has been a problem in C7A types such as 10W C7 and 10W HV S6. Here a very close control of getter cup (and mount) level is necessary to immerse the entire coil and avoid immersing the button. If any portion of the coil is not coated with getter, this is what happens: These coils are mounted with slight tension. The ungettered portion comes up to high temperature at flashing more quickly than the rest of the coil. The tension still remaining in the cooler part of the coil causes the hotter portion to stretch, and

12.12.3 UNEVEN GETTERING - (CONTD.)

the rest of the coil contracts. The resulting uneven spacing of the coil causes short life. A similar effect results in a spray gettered hand-mount coil if the getter flakes off from portions of the coil. Also, weak spots in the coil may result because of the temperature gradient at flashing.

12.12.4 LAMP DESIGN

Even with excellent getter practice, it is still possible for a vacuum lamp to become gassy from outgassing if it is burned at a high enough temperature in service. The following are examples of lamps which may become excessively hot if burned in a confining fixture, because of their high wattage in relation to bulb size:

10W C7

33W T6½

35A A15 (approx. 40 watts)

40W T10

56W A21

75W A21 R.S.

In such types, it is advisable to use a getter rich enough in phosphorous so that a noticeable brown color is present in the flashed lamp. The surplus phosphorous on the bulb wall will have an appreciable effect in collecting the gas as it occurs from outgassing.

12.13 GENERAL GETTER RULES

It should be pointed out that getter cannot be expected to produce a good lamp unless good lamp-making practices are followed. These practices include the following:

1. Proper mount storage in dry clean space, with observance of specified holding time limits.

2. Proper exhaust speed, as specified.

3. Adequate heat for outgassing of bulb and parts during sealing, with emphasis on application of heat early in the sealing cycle.

4. Proper oven temperature in case of tubular bulbs.

5. Avoidance of burning getter at sealing.

12.14 REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

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4. Why Does Lamp Industry Use Cryolite As A Getter Compound? by D. R. Dayton, GTE Sylvania, Estes St., Ipswich, Mass., 01938.
5. Thermochemical Relationships For Phosphorous Getters In Gas-Filled Incandescent Lamps by E. M. Passmore and G. L. Duggan, GTE Sylvania, Danvers, Mass., 01923.
6. Zr - Al Alloy As A Getter by A. Barosi and E. Rabusen. Technical Report TR-26 SAES Getters S.P.A. 1-20151 Milano Italy.
7. Method Of Making Incandescent Lamp
   U. S. Patent #3,989,549.
8. Getter (P_3N_5) For Incandescent Lamps and Similar Devices
   U. S. Patent #3,475,072.
   U. S. Patent #3,784,275.
9. GTE Sylvania - Number System for Getters
   Spec. #2B0500-1E GTE Sylvania, Loring Avenue, Salem, Mass., 01970.
10. Residual Gases in Electron Tubes and Lamps by P. della Porta, Academic Press, 111 Fifth Avenue, New York, N. Y. 10003.

13.0 QUALITY ASSURANCE OF INCANDESCENT LAMPS

Several faults can be found simply by visual inspection. Certain other faults can be found by measurements.

13.1 PUMPING AND GAS-FILLING DEFECTS

Pumping and Gas-filling quality can be assessed only by

a. The judgement by high frequency coiling the lamp

b. The cyanogen test

c. The judgement after lamps have been aged for one hour at 120% rated volts

d. The design life test performance

Vacuum lamp quality is assessed by high frequency coiling and by the ability of the lamp not to flash over (arc) when switched on at 120% of rated volts.

13.2 VISUAL DEFECTS

Uncut wire or wires (serious fault - uncut wires can short on shell of base. Chance of making shell "live" on some type bases.)

Unsoldered or poorly soldered bases
Crooked bases
Poor etch or stamp
Damaged base
Tilted mount
Filament out of support
Crooked bulb
Loose Base
Solder in stem tube
Poor coating (smoke coatings, etc.)
Yellow lamps (excess Phosphorous getter)

13.3 MEASURED DEFECTS

Wrong L.C.L. (measured with gauge)
Wrong M.O.L. (measured with gauge)
Wrong diameter
Base torsion test failure
Low or high Lumens
Low or high watts
Poor base insulation - Meg ohm test
Poor life performance
Low gas pressure - gas-filled lamps
Flash failure on vacuum lamps

13.4 HIGH FREQUENCY COILING

One of the most useful tools for manufacturing and inspecting incandescent lamps of all types is the High Frequency Coil (sometimes called a Tesla coil). Figure 13.4.0 is a general schematic of such a coil. The use of this device is called "coiling".

Typical application of the high frequency coils are as follows:

13.4.1 VACUUM MEASUREMENTS

When a lamp with approx. 10^{-3} Torr or less is coiled, there is no ionization and the bulb remains clear. This is referred to as a "hard" vacuum. Above 10^{-3} Torr the gas ionized starting with a pale color which becomes more vivid as the pressure rises. Above some pressure, the gas no longer ionizes but an arc is generated from bulb wall to the leads and filaments.

"Coiling" is used to inspect a quantity of vacuum lamps. Coiling is done in a dark booth. A fan is necessary for ventilation to remove ozone generated by the high frequency coil. The poor

HIGH FREQUENCY COIL

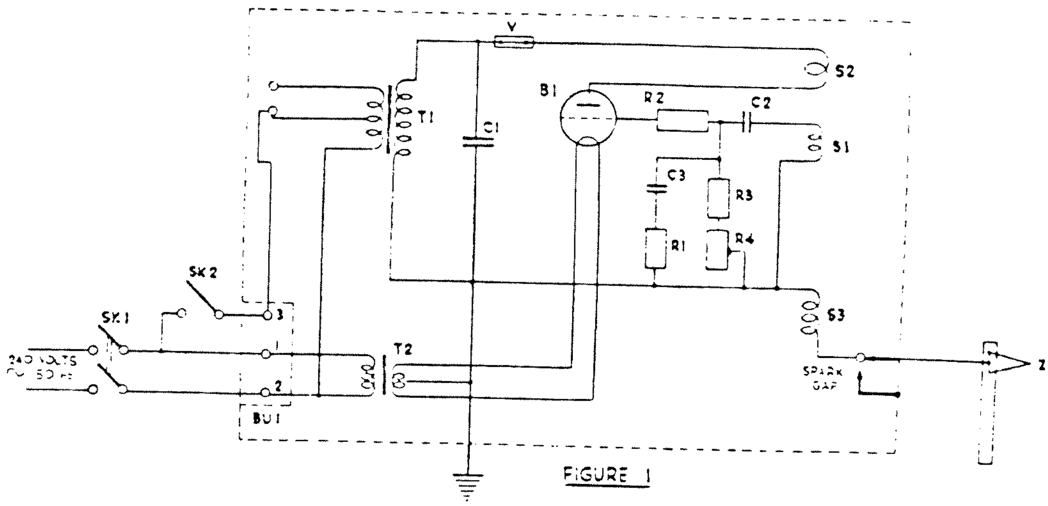


FIGURE 1

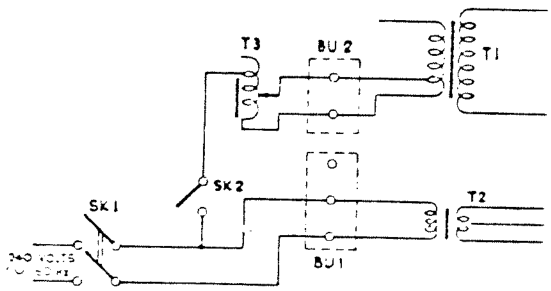


FIGURE 2

SYMBOL	DESCRIPTION	PART CODE NO.
B1	OSCILLATOR VALVE	TB2 5/300
BU1	PLUG AND SOCKET	
C1	D C BOX CAPACITOR 0.1 µF 3400V	48 343 10/5100K
C2	2 FOIL MICA CAPACITOR R470 cF 1500V	48 461 10/470E
R1	RHEOSTAT 200 OHM 40W	88 300 45/A200E
R2	RHEOSTAT 1000 OHM 25W	88 300 44A/1K
R3	WIRE RESISTOR 6300 OHM 16W	88 300 33A/GK3
R4	ENAMELLED POTENTIOMETER 5000 OHM 40W	E198 AC/ A36A 5X
S1,S2,S3	COIL UNIT	E4 521 75
SK1	2 PIN WAFER SWITCH 10 AMP	
SK2	HOOK SWITCH	
V	FUSE 315 mA	
T1	PHILIPS TRANSFORMER 240/900-1400V 380VA	T1 810 09
T2	PHILIPS TRANSFORMER 240/6.3V	T1 700 07
T3	REGULATING TRANSFORMER 240/0-260V 520VA	
ZK1	COILING ELECTRODE	
BU2	PLUG AND SOCKET	

Figure 13.4.0a

The high frequency current is produced by means of an oscillating valve (B1) and HF coils (S1), (S2), (S3). The heater supply for the valve is taken from the transformer (T2) which has a center tapping. The anode current is supplied by transformer (T1). When the complete primary winding is in circuit, a spark length of 1.5 cm. is obtained. When one half of the primary winding is in, a spark length of 3 cm. will result.

The terminal block for the connections for both spark length is placed before transformer (T1).

Coil (S2) is in the anode circuit. Coil (S1) is in the grid circuit.

When a voltage is applied to the anode, coil (S2) will create a voltage in inductances (S1) and (S3). Inductance (S3) has a self capacity which is in parallel with it, thus forming an oscillatory circuit, which will start oscillating in its natural frequency.

The oscillation is maintained as follows:
The oscillation is induced into inductance (S1) by means of its coupling to inductance (S3), and is amplified by the valve. This will continue until the anode voltage has decreased to such an extent as to stop the oscillations. In the following cycle the same process is repeated.

The grid and anode circuits of valve (B1) might start generating in their own frequency which is higher than the frequency of the inductance (S3). In order to prevent this, resistance (R1) and capacitor (C3) in series with each other are connected across the grid leak (R3-R4). Resistance (R4) is adjustable. Consequently, the oscillation, having a higher frequency than the normal one, is stopped. The voltage thus fed back to the grid circuit will cause such losses of energy in resistance (R1) that no generating conditions can be maintained for this frequency. In order to prevent parasitic oscillations through wiring capacities and inductances, a blocking resistance (R2) has been placed before the grid. Blocking capacitor (C1) prevents HF currents entering transformer (T1) A 315 mA fuse (V) is included in the anode circuit.

The Apparatus is connected to 240V A C supply mains via hook switch (SK2) and 2 way switch (SKI). When the hand electrode is hanging on the hook switch (SW2), transformer (T1) is dead.

When the hand electrode is removed from hook switch (SW2), the strength of field of coil (S3) increases. Unless the coil is loaded, this would cause brushing of the coil and the production of creepage paths in the insulation to the housing (earth). This is prevented by making the last winding of coil (S3) of wire much thicker and fitting a spark gap, which will arc over when the voltage becomes excessive. The spark gap consists of a brass globe connected to end of coil (S3) and is plugged into the bush in the center of the insulating plate opposite the globe. There is a bracket spaced at 32mm over the globe.

The length of spark may be varied by adjusting the secondary voltage of transformer (T1). This can be done by varying the transformation ratio (switching from 1.5 to 3 cm spark) or by adjusting the primary voltage by the insertion of a regulating transformer (T3) in series (see figure 2).

Figure 13.4.0b

13.4.1 VACUUM MEASUREMENTS - (CONTD.)

vacuum lamps are easily separated from the "hard" vacuum lamps. The air lamps or leakers are also obvious and easily separated. Several thousand miniature vacuum lamps can be thoroughly inspected in a short time.

"Coiling" is used to monitor the condition of heads on an exhaust machine. The color of the discharge in the bulb as it passes a high frequency coil indicates the pressure in the head. A head with a more vivid or heavier color means that the head leaks or the bulb leaks. Repeat condition is a sure indicator of a head problem.

"Coiling" can be used to inspect the vacuum and flush cycle on an exhaust machine. By using hand-held "coil" and walking around the machine and "coiling" each position. Conclusions can be reached regarding pump conditions, sweeps, leak recovery time, ultimate pressure in lamp etc.

"Coiling" can be used to leak check glass vacuum systems. By moving the probe all over the glass surface, any leaks will show up as small, bright lights or stars. The light is actually an arc which occurs in the leak due to the pressure drop between outside air and inside low pressure (vacuum). The probe should not be held stationary for more than a few seconds because the arc from coils can puncture a thin piece of glass and cause a leak.

"Coiling" is not recommended for microminiature lamps because the energy from the coil can either destroy the filament or cause the lamp to go "gassy" by over-heating the bulb. Lamps below

13.4.1 VACUUM MEASUREMENTS - (CONTD.)

Tl 3/4 are not usually "coiled". Microminiature lamps can be checked by gas current (use lamp as a Piranni tube) or read lamp current in air and then with the lamp immersed in liquid nitrogen. The smaller the difference in current, the better the vacuum.

13.4.2 OUTGASSING GLASS

When a lamp is pumped to a low pressure and then coiled, a blue discharge occurs which fades and stabilizes to some value. If the coil is removed and then returned, only the stabilized color is seen. It is evident that coiling has liberated some gas which is then removed from the lamp by the pumps.

It should be noted that the gas thus liberated cannot be liberated by mere heating of the walls to their softening point; gas can be attached to the walls in some such way that it can be liberated by the discharge but not by heating. Of course, the attachment may consist of chemical combination; it is possible that glass contains hydrogen chemically combined, probably as water. But it should be observed that the hydrogen liberated, if piled up on the glass, would form a layer at least 25 molecules deep. Since the potential driving the discharge in these experiments was often as low as 50 volts, it is hardly to be expected that the electrons or ions could penetrate so far into the glass simply by virtue of the energy which they receive from the discharge. It seems easier to believe that a layer on the surface, subject to the action of these particles, is constantly renewed by diffusion from within.

13.4.2 OUTGASSING GLASS - (CONTD.)

Since it is necessary to remove the gases liberated, it is often desirable to "coil" the lamp at higher pressure (1-4 torr) so that the liberated gas can be removed along with flush gas. The liberated gas is diluted by the flush gas so that residual gas is mostly flush gas.

13.4.3 IDENTIFICATION OF FILL GASES

Argon, Nitrogen, Krypton, Xenon, Hydrogen, etc., are normally used in the manufacture of gas-filled incandescent lamps. When a gas-filled lamp is "coiled" the color of the discharge is an indicator of the fill-gas and purity of the fill gas. The following table shows the basic color when lamp is coiled.

For discharge in air:

Pressure range	Discharge phenomena
$10 - 10^{-1}$ Torr	red or purple glow in the vacuum system, expanding to the full cross section of the tube as the pressure decreases;
$10^{-1} - 10^{-2}$ Torr	discharge continues, in addition green fluorescence on the inner glass wall in the vicinity of the high-frequency electrode outside;
$10^{-2} - 10^{-3}$ Torr	red glow reduced, at about 10^{-3} Torr only a green fluorescence on the inner wall is visible;
below 10^{-3} Torr	no visible glow.

The colour of the discharge depends on the nature of the gas.

Colour of glow discharge for various gases.

Air:	red to purple
Ammonia:	blue.
Argon:	blue.
Helium:	purple-red to yellow-pink

13.4.3 IDENTIFICATION OF FILL GASES - (CONTD.)

Hydrogen:	blue.
Mercury vapour:	greenish blue.
Neon:	red.
Nitrogen:	red-purple.
Oxygen:	lemon-yellow with reddish core.
Water vapour and hydrocarbons:	white-blue, almost white, faint.
Krypton	white - blue-white.

The color changes with gas purity depending on the contaminant and also the type of discharge from soft glow to direct arcing around the mount.

"Coiling" to measure fill quality of gas-filled lamps takes practice but can be quite accurate when done by a trained observer.

The Cyanogen Test requires some optics and electronic circuitry but an integral component is a high frequency coil and again the color or wave lengths of the discharge are analyzed to indicate the purity of the fill-gas. Cyanogen (CN) spectrum is altered by the presence of oxygen and water vapor. A reduction in a normal amount of CN is an indicator of a contaminated and short life lamp.

13.4.4 AN UNEXTINGUISHABLE FLAME

A continuous arc from a coil can be used to light a gas-air-oxygen burner. Some burner applications such as the blow hole burner for GLS stems and tipping fires for all lamps are a source of burner outage problems. A coiler can be mounted to continuously supply a "lite" for the burner when needed.

13.4.5 LEAK DETECTOR

The color and brilliance of the ionized gases increase with pressure in the range of 7.5 microns (1 Pa) up to about 3000 Pa (22.5 Torr). The luminous energy can be detected by a photocell. By calibrating the photocell circuitry, a precision leak detector can be set up for vacuum lamps.

13.5 AIR LAMPS

Air lamps are gross leakers which show up at light up or spark coiling. The following are the usual causes of air lamps.

1.	Cracked Bulb	Thermal Shock or scratch on bulb.
2.	Cracked Stem Press	Fault in stem making and/or stem annealing.
3.	Cracked Seal	Fault in sealing in or basing fires too hot.
4.	Lead Wire Leaks	(a) "Cold Press" Fault in stem-making. (b) Leaks due to weak bond between glass and dumet indicated by dark red seal color - fault in stem-making.
5.	Cracked Tip	Fault in tipping off - more likely on vacuum lamps.
6.	Leaky seals on smoked or white lite lamps	Particles of coating material sealed into bulb and flare seal. Cause is bad neck cleaning or marking.

NOTE: The leak may be a "slow leak" which is not indicated by the high frequency coiling initially but can only be detected after a hold period of several hours or days.

13.5 AIR LAMPS - (CONTD.)

7.	"Wings" on seals.	Sealing-in fault. Glass is liable to crack causing a leak (especially if the wing is broken off with pliers or tweezers).
8.	Blown out tips	Tipping-off fault on pump.
9.	Hole in seal	Fault in sealing-in.
10.	Broken exhaust stem	Handling - weak stem.

13.6 FLASH FAILURE (VACUUM LAMPS)

Causes 1. A lamp will "flash-over" if there is air or a gas at low pressure in the lamp. This condition is present when there is a "slow leak" in the lamp caused by a glass crack (usually cracked tips) or by a press leak or wire leak.

2. A lamp is liable to flash-over if the aging of the filament has not been completed satisfactorily. The lamp must be run up to 120% rated volts unballasted and held at this voltage for 15 seconds. The lamp should coil "dead hard" after aging by the high frequency coil test.

Causes:

3. Lead-in wires too close.
4. Clamping of the filament on mounting mill faulty.
5. Gettered filaments in stock for too long a time. (phosphorous has become acidic).
6. Glass dust in lamp.

13.7 JUDGMENT BY HIGH FREQUENCY COILING

13.7.1 GAS-FILLED LAMPS:

The initial judgment of pumping and gas-filling quality is made after the lamps have been based and aged. All lamps are burned and tested with the high frequency coil. Phosphorous gettered lamps which show "yellow" on the coil after burning must be rejected. This is an indication of lack of phosphorous on the filament.

Lamps which show "POOR" on the coil: If all lamps of a batch show "Poor" on the coil the indication is that EITHER the pumping system is faulty (leak in the gas lines, P_2O_5 driers need changing, dirty pumping system, dirty gas lines, bad cylinder of gas, unwanted vapours in the system) OR the mounted stems/unmounted stems have been left standing too long before sealing-in/pumping. Stems contaminated by grease or dirt show the same on the high frequency coil.

If only SOME of the lamps of the batch show "POOR" on the high frequency coil this is an indication that isolated heads on the pump are faulty (very small leak in a rubber, head not closing properly, etc.) There may be in the same batch degrees of quality, varying from "GOOD" to "POOR" - this is an indication that a leaky lamp or open head on this pump not valved off by the Leak Detector has contaminated lamps before and after the leaky lamp or open head.

13.7.2 VACUUM LAMPS:

All lamps must be 'dead-hard' when tested with the high frequency coil after ageing.

13.8 JUDGMENT AFTER ONE HOUR'S BURNING AT 120% RATED VOLTS.

13.8.1 GAS-FILLED LAMPS:

High Frequency Coiling. This should be a very soft purple color.

Appearance. This molybdenum supports must be perfectly clean. Darkening of the supports 1 - 4 M/M from the filament is an indication of the presence of water vapour in the lamp. The degree of darkening indicates the extent of water vapour attack. Water vapour has a disastrous effect on the life of the lamp (it rapidly accelerates the evaporation of the filament).

13.8.2 VACUUM LAMPS:

High Frequency Coiling. The lamp must be "dead-hard".

Flash-over tests. (Test when the lamps are at room temperature). The lamps must not flash over when switched on at 120% Rated Volts.

13.9 FACTORS WHICH DETERMINE THE LIFE OF A LAMP WHEN OPERATING UNDER NORMAL CONDITIONS AND AT RATED VOLTS.

1. The correct filament (correct light output). Correctly mounted filament.
2. Pumping and gas filling quality.
3. Glass parts which will not crack during the lamp's burning.
4. Perfect glass to metal seal (in the press which will NOT CRACK OR LEAK.

13.9.1 SHOCK AND VIBRATION TESTS

(See Chapter I Lamp Performance)

13.9.2 CALCULATIONS OF RATED LIFE

(See Chapter I Lamp Performance)

13.9.3 CALCULATION OF LPW AT RATED LIFE

(See Chapter I Lamp Performance)

13.10 QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS

1. QUALITY IS BUILT INTO THE PRODUCT.

Faults cannot be rectified by inspection, but can be prevented by adequate and efficient control at every stage of manufacture.

INSPECTION SHOULD PRODUCE A RUNNING COMMENTARY ON THE QUALITY so that corrective measures, if necessary, can be taken immediately, thus preventing rejects.

LAMP MATERIALS ARE EXPENSIVE.

2. In order to achieve and maintain consistently good quality of the product other considerations must be taken into account:

a) Cleanliness of machinery and equipment. General cleanliness of the factory (Good Housekeeping).

b) Seeing that the machinery and mechanisms are regularly lubricated.

c) Adequate and efficient machine maintenance. (Replacement of worn or burnt parts when necessary).

d) WORKING TO INSTRUCTIONS AND LAMP SPECIFICATIONS.

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONTD)

2. e) Check to see that components or assemblies from preceding operations are satisfactory. For example: it is wasteful and inefficient to seal-in mounted stems when the batch is known to contain stems having faults (such as "no hole in press", burnt wires, leaky press. The batch should be 100% inspected and the stems with faults rejected.

Certain controls must be done regularly (Gas pressure measurements, burning lamps for 1 hour and assessing general lamp quality, photometry, base torsion testing, life testing). Such controls are done by a separate person who must report back to the supervisor IMMEDIATELY any feature which is out of control.

OPERATION		INSPECT AND CONTROL
Flange-making	Inspect	1. Shape
		2. End Glazing
		3. Chips or cracks
		4. Dimensions
	Control:	Strain under Strain Viewer (Polariscope)
Stem-making	Inspect:	1. Alignment
		2. Wires correct colour and NOT burnt
		3. Leaky press
		4. Exhaust stem well blown out
		5. Hole in press
		6. Well blown out
		7. All dimensions
		8. Chips or cracks
		9. Correct leading-in wires
		10. Sheathing wire around fuse not cracked
		11. Ballotini filled correctly

13.10 QUALITY-INSPECTION AND CONTROL OF PRODUCTION PROCESS - (CONT)

OPERATION		INSPECT AND CONTROL
Stem-making	Control:	Strain under Strain Viewer. Strength of exhaust tube. ANNEALER.
Mounting Mill	Inspect:	1. Pigtails not shorting in stud 2. Cracked stud 3. Filament not distorted 4. Correct filament pinching-in 5. Correct number of pigtails 6. Even spacing of pigtails 7. Pigtail eyes closed 8. Correct filament-tension 9. Lead tip spacing correct 10. Dimensions 11. Phosphorous dosing
	Control:	1. Phosphorous dosing (within ½ hour after starting production and then continuously by checking phosphorous tint of lamps in the final test box) 2. Phosphorous pot and Methylated Spirit dripper (control continuously) 3. The correct rating of filament.
Sealing-in	Inspect:	1. Cracks or chips 2. Shape 3. Neck forming 4. Stamping and burning-in 5. Dimensions 6. No wings on seals 7. No sharp seals 8. No cracked presses

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONT'D)

OPERATION		INSPECT AND CONTROL
Sealing-in (C ntd.)	Control:	1. Heat distribution burners.
		2. Sealing-in pins - free access of air through center of pins
		3. Annealing burners
		4. Sealing pins all the same height and free to move easily
		5. Cradles and bridge pieces same height
		6. Neck moulds set correctly
		7. Neck mould burners
Pumping:	Inspect:	Form, length and shape of tips. (VERY IMPORTANT ON VACUUM LAMPS)
	Control:	1. Leak Detector is operating satisfactorily.
		2. Oven temperature when "hot" pumping
		3. Each position with high frequency coil (when starting and regularly throughout the production period)
		4. Check lamps from each head with high frequency coil regularly
		5. Check gas cylinders. When a new cylinder is put in circuit check all connections with soapy water for leaks on the high pressure side
		6. Check P_2O_5 driers
		7. Check oil reservoirs to valve plates
Basing:	Inspect:	1. Uncut wires
		2. Badly soldered or unsoldered
		3. Crooked bases

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONTD)

OPERATION		INSPECT AND CONTROL
Basing: (Contd.)	Inspect:	4. Basing cement not baked or over-baked
		5. Solder down flange tube
		6. Leading-in wires touching
		7. Damaged bases
	Control:	1. Check voltage and resistance settings
		2. Check burners and check to see that basing cement is properly baked. Check color after baking - should be more brown than green
		3. Check to see that bases are not too hot when soldering
		4. Check wire cutting, flexing and soldering

NOTE: When using bases which require side solder, special attention is required - keep flame away from the glass bulb neck.

AGEING

A. Gas-filled lamps. Gas-filled lamps are aged during the basing operation.

Control: 1. Check voltage and resistance settings on Control Panel.

B. Vacuum lamps. Vacuum lamps are aged on Ageing machine (to render the lamps **"dead hard"** on high frequency coil).

Control 1. Check voltage and resistance settings on Control Panel.

Control 2. Check to see that all positions on the Ageing Machine are in good order and that lamps light up on every position.

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONTD)

Inspection and High Frequency Coiling

GAS-FILLED SINGLE COIL LAMPS.

1. In frame provided turn the tray of lamps so that they are base-up.

2. Inspect for:
   a) Uncut wires,
   b) Bad soldering,
   c) Cement on bases

Lamps showing these defects must be taken out of the tray and passed to the repair bench.

3. High-frequency Coil the lamps (leaky lamps must be removed). Phosphorous gettered lamps which show "yellow" on the coil should be noted.

4. Run the lamps up to 20% over rated voltage SLOWLY. NOTE: CHECK VOLTAGE.

5. Run the lamps down to low voltage. Inspect filament formation. Any lamps which show "knocked filaments" or "distorted filaments" must be rejected. Lamps which show part of filament unlit must be rejected (caused by pigtails shorting in the stud).

6. Switch off.

7. High-Frequency coil the lamps. Leaky lamps must be removed (rejects). Phosphorous gettered lamps which show "yellow" on the coil should be removed (rejects).

   If the lamps which initially showed "yellow" on the coil show satisfactory on the second coiling they can pass. Lamps which do not

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONTD)

Inspection and High Frequency Coiling

GAS-FILLED SINGLE COIL LAMPS.

7. light up must be inspected (broken filament - broken fuse - which are rejects). (Poor contact, wire not threaded, which are repairable).

8. RECORD REJECTS TRAY BY TRAY ON FORM PROVIDED. REJECT LAMPS MUST BE RETAINED UNTIL AFTER EXAMINATION.

Gas-filled Coiled-coil lamps (this includes 40 - 100 white light lamps)

Exactly the same procedure as for gas-filled single-coil lamps except for Point 5.

9. Run the lamps up to 20% over rated voltage SLOWLY and hold for 10 seconds.

NOTE: CHECK VOLTAGE. THE GAS-FILLING - PUMPING QUALITY IS ASSESSED BY THE HIGH FREQUENCY COIL AND ANY OBSERVED VARIATION FROM THE ACCEPTED STANDARDS MUST BE REPORTED IMMEDIATELY.

Inspection and High Frequency Coiling - After Ageing on Ageing Machine.

(B) VACUUM LAMPS.

1. In Frame provided turn the tray of lamps so that they are base-up.

2. Inspect for:
   a) Uncut wires,
   b) Bad soldering,
   c) Cement on bases.

   Lamps showing these defects must be taken out of the tray and passed to the repair benches.

3. High Frequency coil the lamps. Leaky lamps must be removed (rejects).

   LAMPS WHICH ARE NOT DEAD HARD ON THE COIL MUST BE REMOVED AND PASSED BACK TO THE AGEING MACHINE FOR REAGEING.

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONTD)

Inspection and High Frequency Coiling - After Ageing on Ageing Machine.

(B) VACUUM LAMPS.

4. RUN THE LAMPS UP TO 20% OVER RATED VOLTAGE SLOWLY AND ALLOW THE LAMPS TO BURN AT THIS VOLTAGE FOR 15 SECONDS.

   CHECK VOLTAGE.

5. RUN THE LAMPS DOWN TO LOW VOLTAGE. Inspect filament formation. Any lamps which show "knocked filaments" or distorted filaments show part of the filament unlit must be rejected (caused by pigtails shorting in the stud).

6. Switch off.

7. High Frequency - coil the lamps. Leaky lamps must be rejected.

8. RECORD REJECTS TRAY BY TRAY ON FORM PROVIDED. REJECTED LAMPS MUST BE RETAINED UNTIL AFTER EXAMINATION.

NOTE: THE RECORDING OF REJECTS, TRAY BY TRAY, GIVES A RUNNING ACCOUNT OF THE QUALITY PERFORMANCE OF THE GROUP AND RUNNING FAULTS QUICKLY HIGHLIGHTED SO THAT CORRECTIVE MEASURES CAN BE IMPLEMENTED IMMEDIATELY.

SECOND CONTROL

After manufacture, and before packing, each batch of lamps must pass the second quality control station. 10% of each batch are inspected and controlled for quality and if the sample contains more than the agreed level of faults a further 10% must be checked. If the faults are contained in the further sample at the same, or

13.10-QUALITY - INSPECTION AND CONTROL OF PRODUCTION PROCESS-(CONTD)

at a higher level, the whole batch must be 100% re-inspected. After re-inspection, the 10% control must be exercised.

(THE 10% MUST BE TAKEN FROM THE BATCH AT RANDOM) RECORDS MUST BE KEPT OF EVERY BATCH TESTED. THIS GIVES A RUNNING ACCOUNT ON THIS SECOND CONTROL.

13.11 INDEPENDENT PRODUCTION CONTROLS

PUMPING QUALITY

a) Gas-filled Clear and Pearl.

6 lamps are taken from each group every hour. After High Frequency coiling the lamps are burned base up at 120% rated volts for 1 hour.

After burning the lamps are High Frequency coiled and the inside of the lamps carefully examined.

THE FILAMENT SUPPORTS MUST BE PERFECTLY CLEAN.

A darkening of the supports 1-5 mm. from the filament is an indication of the presence of water vapour in the lamp and the degree of darkening indicates the extent of water vapour. Judgment is made of the High Frequency coiling before and after 1 hour's burning. The 6 lamps are inspected for all features (including dimensions).
Bases are torsion tested and measured for insulation.

b) Vacuum lamps.

6 lamps are taken from the group every hour. After High Frequency coiling the lamps are burned base-up at 120% rated volts for 1 hour.

13.11 INDEPENDENT PRODUCTION CONTROLS - (CONTD.)

PUMPING QUALITY

b) Vacuum lamps. The lamps are inspected for all features (including dimensions).
Bases are torsion tested and measured for insulation.

FLASH TEST: (Switching the lamps on at 120% rated volts. Lamps must be in holders base-up).
10% of lamps taken at random for Flash Test.
If "flash-overs" are found 100% of batch must be flash tested.

NOTE: The test is to switch on at 120% rated volts, NOT to run them up to maximum volts.

c) Whitelight lamps-Same procedure as for Gas-filled, Clear and Pearl lamps.
In addition, take 6 lamps per hour and burn base down at 120% rated volts. There should be no black-streaking or darkening on the inside of the bulb (examine by breaking open one or two of the lamps).

d) Gas Pressure A lamp is taken from each group every 4 hours and measured for gas pressure.

e) Photometry 6 lamps are taken from each group every 4 hours and measured for light output and current. In addition, immediately after a change of filament rating, a Photometry and Current check is made.

13.12 QUALITY CONTROL ORGANIZATION AND FUNCTIONS

There are five major areas in which Quality Control operates, viz. a) M.I.D., b) Process Control, c) Final Inspection, d) Test and Measurements, and e) Customer Relations.

a) M.I.D. - The Material Inspection Department is usually under Quality Control. This phase of the operation concerns itself with the inspection and disposition of material incoming to the plant such as glass, lead wires, bases, coils, etc. In many cases, where previous history is satisfactory, the inspection is quite small and of a token nature.

The function of this operation is to prevent non-standard or out-of-tolerance parts from getting into the manufacturing process and causing shrinkage or down time.

b) PROCESS CONTROL - This operation is sometimes under the Product Engineering group. It is quite important that it be done effectively. Such controls are extended to overhang, lead tip spacing, glass strain analysis, etc. It is quite obvious that proper controls on the process will result in reduced shrinkage and improved quality.

c) FINAL INSPECTION - This function of the Quality Control group assures that only acceptable quality is shipped from the plant. The sampling is usually in accordance with MIL-STD-105D and for incandescent lamps the acceptable quality level is 0.65%. In practice, it is better. Rejected lots are returned for re-inspection.

13.12 c) FINAL INSPECTION - (CONTD.)

Since incandescent lamps have a tendency to have some additional failures (air lamps) with time, the Quality Control group holds a small portion of the inspected production for thirty days as a check. This provides additional information as to the quality of lamps leaving the factory.

d) TESTS AND MEASUREMENTS - Quality Control is responsible for the performance of photometric, life and other environmental tests. Current and lumen ratings are taken and translated into wattage and LPW. Life tests, both accelerated (force) and normal are made, and results studied for possible improvements. In addition, drop tests, base strength tests, and other performance tests are made as required.

It is important that photometers be calibrated to precise standards and that voltages used are properly regulated.

e) CUSTOMER RELATIONS - The Quality Control group as part of its function periodically recalls lamps from field warehouses and makes an appraisal of lamps in the field. All important complaints and RRARs funnel through Quality Control for corrective action.

f) SUMMARY - A good and effective quality organization is essential to the success of the product and plant. It is the consumers' representative in the plant. However, quality in a product is achieved only through the combined efforts of all and an acceptance of the slogan "Quality is everybody's business."

13.13 ANALYSING THE DATA

One of the commonest problems facing the engineer is that of summarizing a number of experimental observations by picking out the important features of the data. Only then will it be possible to try and interpret the results. The simple methods of analysing data which are considered in this chapter are widely used and are often given the collective title 'Descriptive Statistics'.

It is important to realize from the outset that the observations are usually a sample from the set of all possible outcomes of the experiment (sometimes called the population). A sample is taken because it is too expensive and time-consuming to take all possible measurements. Statistics are based on the idea that the sample will be 'typical' in some way and that it will enable us to make predictions about the whole population.

The data usually consists of a series of measurements on some feature of an experimental situation or on some property of an object. The phenomenon being investigated is usually called the variate.

13.13.1 PICTORIAL METHODS

It is always a good idea to plot the data in as many different ways as possible, as much information can often be obtained just by looking at the resulting graphs.

13.13.2 THE HISTOGRAM

A histogram is a representation of a frequency distribution by means of rectangles whose widths represent class intervals and whose

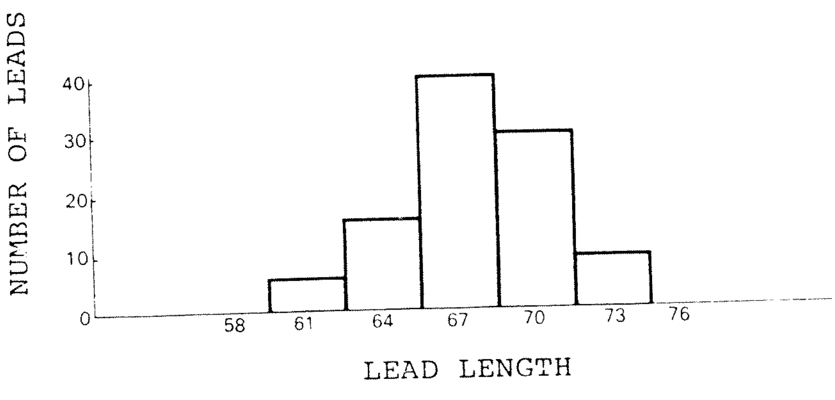
13.13.2 THE HISTOGRAM - (CONTD.)

heights represent corresponding frequencies. It is best illustrated by an example:

EXAMPLE I.

The length of 100 lead wires were measured to the nearest mm and tabulated as follows:

Length	Number of Leads
60-62	6
63-65	15
66-68	40
69-71	30
72-74	9
TOTAL	100



Histogram of data - Example 1

13.13.3 HOW TO DRAW A HISTOGRAM

(1) Allocate the observations to between five and twenty class intervals. In Example 1 (60-62) mm is a class interval.

(2) The class mark is the midpoint of the class interval. All values within the interval are considered concentrated at the class mark.

(3) Determine the number of observations in each interval.

(4) Construct rectangles with centres at the class marks and areas proportional to the class frequencies. If all the rectangles have the same width then the heights are proportional to the class frequencies.

The choice of the class interval and hence the number of intervals depends on several considerations. If too many intervals are used then the histogram will oscillate wildly but if too few intervals are used then important features of the distribution may be overlooked. This means that some sort of compromise must be made. As the number of observations is increased the width of the class intervals can be decreased as there will be more observations in any particular interval.

Histogram shapes. Histograms come in all shapes and sizes. Some of the common shapes are illustrated below.

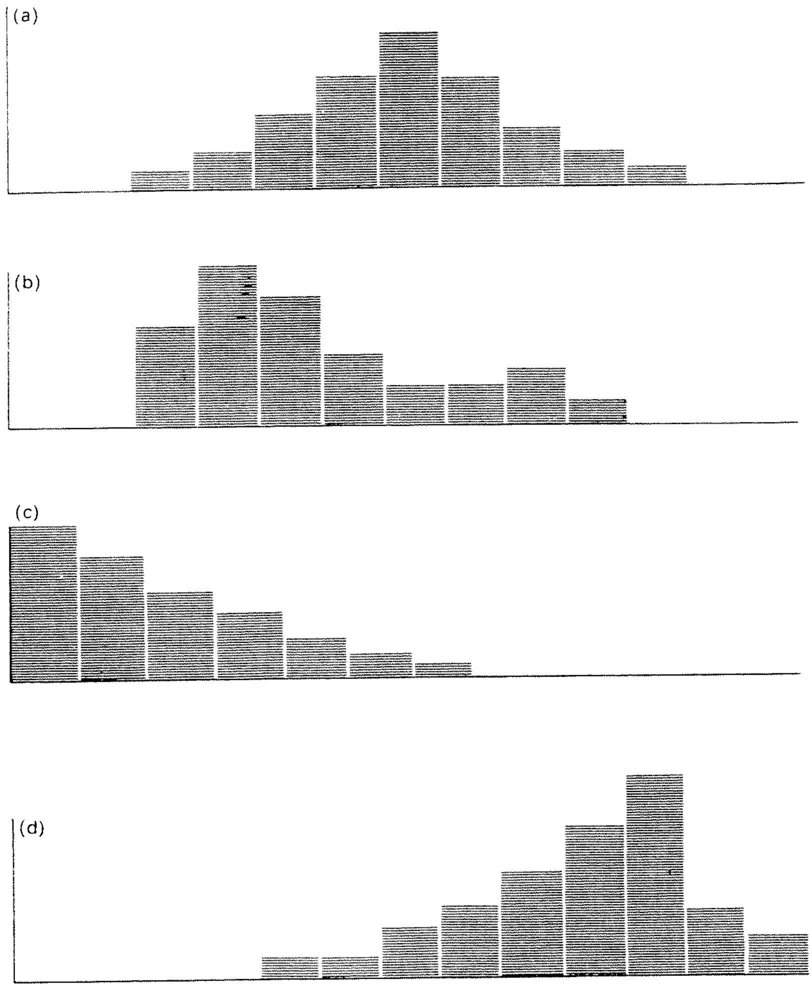
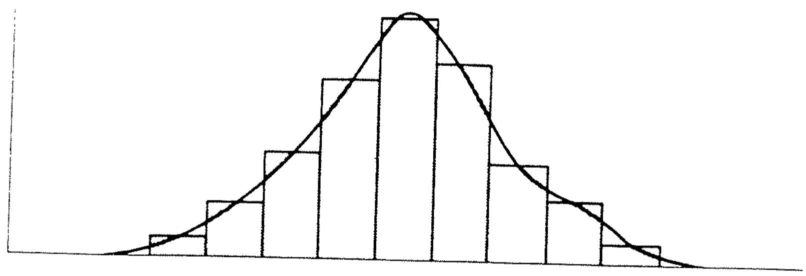


Figure 5 Various histograms
(a) symmetric or bell-shaped
(b) skewed to the right or positively skewed
(c) reverse *J*-shaped
(d) skewed to the left or negatively skewed

FREQUENCY CURVE. Where there are a large number of observations the histogram may be replaced with a smooth curve drawn through the midpoints of the tops of each box. Such a curve is called a frequency curve.



Frequency curve

The above type of curve would be expected if number of failures at increasing life of incandescent lamps were plotted. The early failures due to defects would be to the left and long lives due to lower efficiency, superior filament wire etc., would be to the right and rated or average life would be the mid-point.

Weibull, Normal Law, or other cumulative percentage distribution plots are also useful for visualizing statistical distribution data.

13.13.4 ARITHMETICAL METHODS

In addition to the graphical techniques, it is often useful to calculate some figures to summarize the data. Any quantity which is calculated from the data is called a statistic (to be distinguished from the subject statistics). Thus a statistic is a function of the measurements or observations.

Most simple statistics can be divided into two types; firstly quantities which are 'typical' of the data and secondly quantities which measure the variability of the data. The former are usually called measures of location and the latter are usually called measures of spread.

13.13.5 MEASURES OF LOCATION

There are three commonly used measures of location, of which the mean is by far the most important.

13.13.5.1 THE MEAN

Suppose that n measurements have been taken on the variate under investigation, and these are denoted by $x_1, x_2, \ldots\ldots, x_n$. The (arithmetic) mean of the observations is given by

$$\bar{x} = \frac{x_1 + x_2 + \ldots + x_n}{n}$$

In everyday language we say that $\bar{x}$ is the average of the observations.

13.13.5.1 THE MEAN - (CONTD.)

EXAMPLE 1: The lives of 10 lamps are as follows:

500, 550, 575, 625, 650, 700, 725, 750, 775, 825, Hours.

Find the average life.

$$\bar{X} = \frac{500+550+575+625+650+700+725+750+775+825}{10} = 667.5 \text{ Hrs.}$$

Average lamp life = 667.5 Hours.

EXAMPLE II: Find the mean life of a group of 100 lamps with lives and frequency in the following table:

Number of Lamps	Lamp Life
10	500
30	625
40	700
10	750
10	860

$$\frac{(500 \times 10) + (625 \times 30) + (700 \times 40) + (750 \times 10) + (860 \times 10)}{100} = \bar{X}$$

$\bar{X}$ = 678.5 Hours = mean life of the lamps.

13.13.5.2 THE MEDIAN

The median is occasionally used instead of the mean, particularly when the histogram of the observations is skewed. It is obtained by placing the observations in ascending order of magnitude and then picking out the middle observation. Thus half the observations are numerically greater than the median and half are smaller.

13.13.5.2 THE MEDIAN - (CONTD.)

EXAMPLE:

The weight of twelve filaments selected at random from one group are:

9, 20, 11, 6, 10, 10, 14, 8, 9, 9, 12, 9, mg

This gives $\bar{X}$ = 10.6 mg

Rewriting the observations in ascending order of magnitude we have

6, 8, 9, 9, 9, 9, 10, 10, 11, 12, 14, 20 mg

As there are an even number of observations the median is the average of the sixth and seventh values, namely nine and a half. (9.5 mg)

As eight of the observations are less than the sample mean, it could be argued that the median is 'more typical' of the data.

In Chapter I, average or rated life was calculated several ways. The method where rated life is defined as the point where 50% of sample has failed is actually a calculation of the median life.

13.13.5.3 THE MODE

This is the value of the variate which occurs with the greatest frequency. For discrete data the mode can easily be found by inspection. For continuous data the mode can be estimated by plotting the results in a histogram and finding the midpoint of the tallest box. Thus in example of lead length (13.14.2), the mode is 67 mm.

13.13.5.4 COMPARISON

As we have already remarked, the mean is by far the most important measure of location. When the distribution of results is roughly symmetric, the mean, mode and median will be very close together anyway. But if the distribution is very skewed there may be a considerable difference between them and then it may be useful to find the mode and median as well as the mean.

13.13.5.5 RANGE

This is the difference between the largest and smallest observation. It can be very useful for comparing the variability in samples of equal size but is unfortunately affected by the number of observations; the more observations taken, the larger the range will be. So it is not a fixed characteristic of the population.

13.13.6 VARIANCE AND STANDARD DEVIATION

The sample variance S^2 of n observations, $X_1, X_2, \ldots\ldots, X_n$, is given by

$$S^2 = \frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + \ldots + (X_n - \bar{X})^2}{(n-1)}$$

$$= \sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n-1}$$

The standard deviation s of the sample is obtained by taking the square root of the variance.

$$s = \sqrt{\left[\sum_{i=1}^{n} \frac{(X_i - \bar{X})^2}{n-1}\right]}$$

13.13.6 VARIANCE AND STANDARD DEVIATION - (CONTD.)

The standard deviation is in the same units as the original measurements and for this reason it is preferred to the variance as a descriptive measure. However, it is often easier from a theoretical and computational point of view to work with variances. Thus the two measures are complementary.

In order to calculate a variance on a desk calculating machine, it is usually more convenient to rearrange the form as follows:

$$s^2 = \frac{\left\{\left(\sum_{i=1}^{n} x_i^2\right) - n\bar{x}^2\right\}}{(n-1)}$$

EXAMPLE:

Find the range, variance and standard deviation of the following 6 observations.

0.9, 1.3, 1.4, 1,2, 0.8, 1.0

Range = 1.4-0.8=0.6

$\bar{x} = \frac{6.6}{6} = 1.1$

$\sum x^2 = (0.9)^2+(1.3)^2+(1.4)^2+(1.2)^2+(0.8)^2+(1.0)^2$

$\sum x^2 = 7.54$

$s^2 = \frac{(7.54 - 6(1.1)^2) = 0.056}{5} = 0.056$

$s = 0.237$

13.13.7 COEFFICIENT OF VARIATION.

We have seen that the standard deviation is expressed in the same units as the individual measurements. For some purposes it is much more useful to measure the spread in relative terms by dividing the standard deviation by the sample mean. The ratio is called the coefficient of variation.

$$\text{(coefficient of variation)} = \frac{s}{x}.$$

For example a standard deviation of 10 may be insignificant if the average observation is around 10,000 but may be substantial if the average observation is around 100.

Another advantage of the coefficient of variation is that it is independent of the units in which the variate is measured, provided that the scales begin at zero. If every observation in a set of data is multiplied by the same constant, the mean and standard deviation will also be multiplied by this constant, so that their ratio will be unaffected. Thus the coefficient of variation of a set of length measurements, for example, would be the same whether measurements were made in centimetres or inches. However, this is not true, for example, for the centigrade and Fahrenheit scales of measuring temperature where the scales do not begin at zero.

13.13.8 CURVE FITTING

13.13.9 SCATTER DIAGRAM

Suppose that n pairs of measurements, (X_1,Y_1), (X_2,Y_2), ..., (X_n,Y_n), are made on two variables x and y. The first step in the

13.13.9 SCATTER DIAGRAM - (CONTD.)

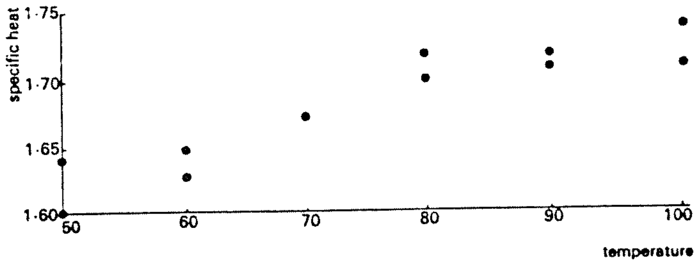
investigation is to plot the data on a scatter diagram in order to get a rough idea of the relationship (if any) between x and y.

EXAMPLE 1:

An experiment was set up to investigate the variation of the specific heat of a certain chemical with temperature. Two measurements of the specific heat were taken at each of a series of temperatures. The following results were obtained:

Temperature °C	*50*	*60*	*70*	*80*	*90*	*100*
Specific heat	1·60	1·63	1·67	1·70	1·71	1·71
	1·64	1·65	1·67	1·72	1·72	1·74

Plot the results on a scatter diagram.



It is often possible to see, by looking at the scatter diagram, that a smooth curve can be fitted to the data. In particular if a straight line can be fitted to the data then we say that a linear relationship exists between the two variables. Otherwise the relationship is non-linear.

Situations sometimes occur, particularly in physical and chemistry, in which there is an exact functional relationship between the two variables and in addition the measurement error is very small. In such a case it will usually be sufficiently accurate to draw a smooth curve through the observed points by eye. Here there is very little experimental uncertainty and no statistical

13.13.9 SCATTER DIAGRAM - (CONTD.)

analysis is really required.

However, most situations are not so clear cut as this, and then a more systematic method is required to find the relationship between the two variables. In the first part of this Section we will discuss the situation where the values of one of the variables are determined by the experimenter. This is called the controlled, independent or regressor variable. The resulting value of the second variable depends on the selected value of the controlled variable. Therefore, the second variable is called the dependent or response variable. However, the problem is usually complicated by the fact that the dependent variable is subject to a certain amount of experimental variation or scatter.

Thus, in Example 1, the temperature is the controlled variable and the specific heat is the dependent variable. At a fixed temperature, the two observations on the specific heat vary somewhat. Nevertheless, it can be seen that the average value of the specific heat increases with the temperature.

The problem now is to fit a line or curve to the data in order to predict the mean value of the dependent variable for a given value of the controlled variable. If the dependent variable is denoted by y and the controlled variable by x, this curve is called the regression curve, or line, of y on x.

We will begin by considering the problem of fitting a straight line to n pairs of measurements, $(x_1,y_1),\ldots,(x_n y_n)$, where the y_i are subject to scatter but the x are not. A straight line can

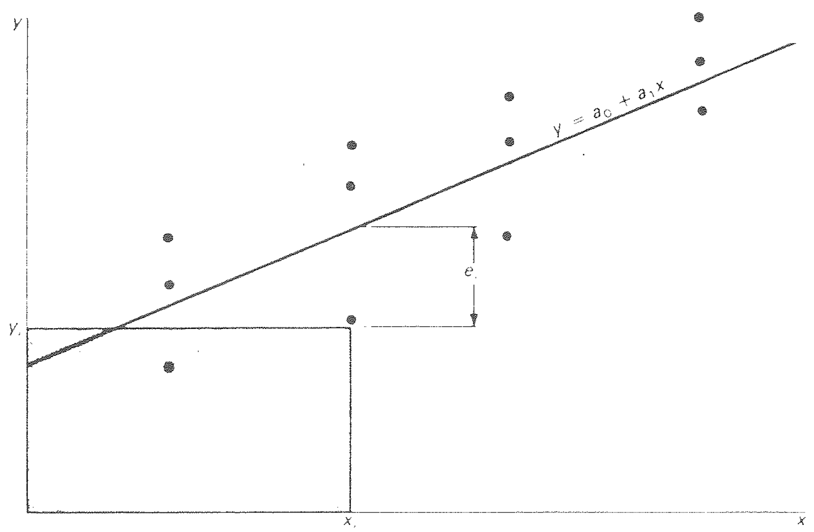
13.13.9 SCATTER DIAGRAM - (CONTD.)

be represented by the equation:

$$y = a_o + a_1 x.$$

The task is to find estimates of a_o and a_1 such that the line gives a good fit to the data. One way of doing this is by the 'method of least squares'. At any point x_i the corresponding point on the line is given by $a_o + a_1 x_i$, so the difference between the observed value of y and the predicted value is given by

$$e_i = y_i - (a_o + a_1 x_i).$$



The least squares estimates of a_o and a_1 are obtained by choosing the values which minimize the sum of squares of these deviations. The sum of the squared deviations is given by

$$S = \sum_{i=1}^{n} e_i^2$$

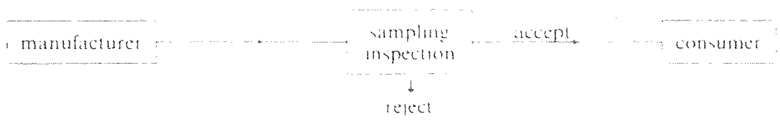
$$= \sum_{i=1}^{n} \left[Y_i - \left(a_o + a_1 x_i \right) \right]^2$$

13.13.9 SCATTER DIAGRAM - (CONTD.)

At this point, the mathematics are becoming a task. With modern hand calculators, the formula for the curve can be arrived at easily. Generally, the curve for lamp data are power curves $y = b\ x^m$, log curves $y = b + \quad x$ or exponential curves $y = b\ e^{mx}$. Programable hand calculators like T1-59 or T1-52 have such programs and will also calculate the confidence factor which for a perfect fit would be 1.000.

13.14 ACCEPTANCE SAMPLING

Any manufacturing process will inevitably produce some defective items. The manufactured items will often be supplied by the manufacturer to the consumer in batches or lots, which may be examined by the manufacturer before shipment or by the consumer before acceptance. The inspection often consists of drawing a sample from each batch and then deciding whether to accept or reject the batch on the evidence provided by the sample. A variety of sampling schemes exist; the more important of these will be described.



Acceptance sampling

13.14 ACCEPTANCE SAMPLING

A simple type of sampling scheme is one in which a single sample is taken and the batch is accepted if there are not more than a certain number of defective items. For example, we could take a sample size 100 from each batch and reject the batch if there is more than one defective item. Otherwise the batch is accepted. Acceptance sampling is used when the cost of inspecting an item is such that it is uneconomic to look at every item in a batch. For example, it must be used in the case where the manufactured item is destroyed by the inspection technique. In contrast, in precision engineering it is more common to inspect every item, in which case there are few statistical problems and most of the following remarks do not apply.

When a batch is rejected by a sampling scheme, it may be returned to the manufacturer, it may be purchased at a lower price or it may even be destroyed. Alternatively rejected batches may be subjected to 100 per cent inspection so that all defective items in the batch are replaced by good items.

Acceptance sampling plans can be divided into two classes. If the items in a sample are classed simply as 'good' or 'defective', then the sampling scheme is said to be sampling by attributes. This qualitative approach contrasts with sampling by variables, in which a quantitative measurement is involved. In other words an attribute scheme does not say how good or how defective an item is. Sometimes this is inevitable. For example, a light bulb will either work or

13.14 ACCEPTANCE SAMPLING

it will not work. There is no in-between state and we must use sampling by attributes.

We shall concentrate our attention on attribute sampling schemes. Fortunately, many of the general principles involved also apply to sampling by variables.

13.15 CLASSIFICATION OF DEFECTS AND DEFECTIVES

METHOD OF CLASSIFYING DEFECTS

A classification of defects is the enumeration of possible defects of the unit of product classified according to their seriousness. A defect is any nonconformance of the unit of product with specified requirements. Defects will normally be grouped into one or more of the following classes; however, defects may be grouped into other classes, or into subclasses within these classes.

VITAL DEFECT

A vital defect is a defect that judgment and experience indicate is likely to result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product; or a defect that judgment and experience indicate is likely to prevent performance of the tactical function of a major end item.

MAJOR DEFECT

A major defect is a defect, other than critical, that is likely to result in failure, or to reduce materially the usability of the unit of product for its intended purpose.

13.15 CLASSIFICATION OF DEFECTS AND DEFECTIVES - (CONTD.)

MINOR DEFECT

A minor defect is a defect that is not likely to reduce materially the usability of the unit of product for its intended purpose, or is a departure from established standards having little bearing on the effective use or operation of the unit.

13.16 PERCENT DEFECTIVE AND DEFECTS PER HUNDRED UNITS

EXPRESSION OF NONCONFORMANCE

The extent of nonconformance of product shall be expressed either in terms of percent defective or in terms of defects per hundred units.

PERCENT DEFECTIVE

The percent defective of any given quantity of units of product is one hundred times the number of defective units of product contained therein divided by the total number of units of product, i.e.:

$$\text{Percent defective} = \frac{\text{Number of defectives}}{\text{Number of units inspected}} \times 100$$

DEFECTS PER HUNDRED UNITS

The number of defects per hundred units of any given quantity of units of product is one hundred times the number of defects contained therein (one or more defects being possible in any unit of product) divided by the total number of units of product, i.e.:

$$\text{Defects per hundred units} = \frac{\text{Number of defects}}{\text{Number of units inspected}} \times 100$$

13.17 ACCEPTABLE QUALITY LEVEL (AQL)

USE

The AQL, together with the Sample Size Code Letter, is used for indexing the sampling plans provided herein.

DEFINITION

The AQL is the maximum percent defective (or the maximum number of defects per hundred units) that, for purposes of sampling inspection, can be considered satisfactory as a process average.

LIMITATION

The designation of an AQL shall not imply that the supplier has the right to supply knowingly any defective unit of product.

SPECIFYING AQLs.

The AQL to be used will be designated in the contract or by the responsible authority. Different AQLs may be designated for groups of defects considered collectively, or for individual defects. An AQL for a group of defects may be designated in addition to AQLs for individual defects, or subgroups, within that group. AQL values of 10.0 or less may be expressed either in percent defective or in defects per hundred units; those over 10.0 shall be expressed in defects per hundred units only.

PREFERRED AQLs.

The values of AQLs given in these tables are known as preferred AQLs. If for any product, an AQL be designated other than a preferred AQL, these tables are not applicable.

13.18 SUBMISSION OF PRODUCT

LOT OR BATCH

The term lot or batch shall mean "inspection lot" or "inspection batch" i.e., a collection of units of product from which a sample is to be drawn and inspected to determine conformance with the acceptability criteria, and may differ from a collection of units designated as a lot or batch for other purposes (e.g., production, shipment, etc.)

FORMATION OF LOTS OR BATCHES

The product shall be assembled into identifiable lots, sublots, batches, or in such other manner as may be prescribed (see 5.4). Each lot or batch shall, as far as is practicable, consist of units or product of a single type, grade, class, size, and composition, manufactured under essentially the same time.

LOT OR BATCH SIZE

The lot or batch size is the number of units of product in a lot or batch.

13.19 ACCEPTANCE AND REJECTION

ACCEPTABILITY OF LOTS OR BATCHES

Acceptability of a lot or batch will be determined by the use of a sampling plan or plans associated with the designated AQL or AQLs.

13.19 ACCEPTANCE AND REJECTION - (CONTD.)

DEFECTIVE UNITS

The right is reserved to reject any unit of product found defective during inspection whether that unit of product forms part of a sample or not, and whether the lot or batch as a whole is accepted or rejected. Rejected units may be repaired or corrected and resubmitted for inspection with the approval of, and in the manner specified by, the responsible authority.

SPECIAL RESERVATION FOR CRITICAL DEFECTS

The supplier may be required at the discretion of the responsible authority to inspect every unit of the lot or batch for critical defects. The right is reserved to inspect every unit submitted by the supplier for critical defects, and to reject the lot or batch immediately, when a critical defect is found. The right is reserved also to sample, for critical defects, every lot or batch submitted by the supplier and to reject any lot or batch if a sample drawn therefrom is found to contain one or more critical defects.

RESUBMITTED LOTS OR BATCHES

Lots of batches found unacceptable shall be resubmitted for reinspection only after all units are re-examined or retested and all defective units are removed or defects corrected. The responsible authority shall determine whether normal or tightened inspection shall be used, and whether reinspection shall include all

13.19 ACCEPTANCE AND REJECTION - (CONTD.)

types or classes of defects or for the particular types or classes of defects which caused initial rejection.

13.20 DRAWING OF SAMPLES

SAMPLE

A sample consists of one or more units of product drawn from a lot or batch, the units of the sample being selected at random without regard to their quality. The number of units of product in the sample is the sample size.

REPRESENTATIVE SAMPLING

When appropriate, the number of units in the sample shall be selected in proportion to the size of sublots or subbatches, or parts of the lot or batch, identified by some rational criterion. When representative sampling is used, the units from each part of the lot or batch shall be selected at random.

TIME OF SAMPLING

Samples may be drawn after all the units comprising the lot or batch have been assembled, or samples may be drawn during assembly of the lot or batch.

DOUBLE OR MULTIPLE SAMPLING

When double or multiple sampling is to be used, each sample shall be selected over the entire lot or batch.

13.21 DEFECT AND SHRINKAGE SYMBOLS FOR INCANDESCENT LAMPS

The following is a list of lamp defects. The letter preceding the number defines whether the defect is VITAL, MAJOR or MINOR as defined in 13.16.

D - VITAL DEFECT

C - MAJOR DEFECT

B - MINOR DEFECT

13.21 DEFECT AND SHRINKAGE SYMBOLS FOR INCANDESCENT LAMPS

100 - 199 ATMOSPHERE

101 - Arc

D 103 - Air Lamp
- A - Glow Test
- B - Burning Test

D 104 - Lamp Gassy

D 105 - Lamp not flashed

D 106 - No gas or Wrong gas present in lamp

C 123 - Glow Persists

C 150 - Discoloration blue

B 151 - Discoloration black
- A - Non-Progressive

B 152 - Discoloration brown
"A" Phosphorous Getter

C 153 - Discoloration black progressive
- A - Sooty clamps or supports
- B - Black bulb

200 - 299 FILAMENT

D 200 - Filament broken

D 201 - Filament missing

202 - Filament fragile

D 204 - Filament burned out

C 210 - Filament interlocked

C 220 - Filament joint defective
- A - Scissors clamp
- B - Tight or loose

C 221 - Filament out of support or Pigtail

D 222 - Filament out of joint

C 223 - Filament tension too high

224 - Minor coil missing

C 227 - Filament joint hot

C 230 - Filament irregular
- A - Loose
- B - Loops too close
- C - Filament too close to lead wire
- D - Kink or curl
- E - Irregular patch of coil
- F - Foreign material in coil

B 231 - Filament tilted

C 232 - Slipover or Minor coil not properly attached

C 233 - Filament wrong
- A - Mixed filaments

C 235 - Gettering poor
- A - Getter missing
- B - Getter poorly applied
- C - Wrong getter

D 270 - Extra Filament

13.21 DEFECT AND SHRINKAGE SYMBOLS FOR INCANDESCENT LAMPS

300 - 399 LEAD WIRES

D 300 - Lead wire broken or missing
- A - Outer lead wire
- B - Press lead wire
- C - Inner lead wire
- D - Joint lead wire

305 - Inner leads shorted (Series Burning)

309 - Lead wire size wrong

C 310 - Lead wires short-circuited

C 311 - Lead wires in contact with base skirt

C 312 - Lead wires too close
- A - Outer lead wires
- B - Press lead wires
- C - Inner lead wires

C 313 - Lead wires too close to support

D 320 - Lead wire not soldered
- A - Eyelet
- B - Shell
- C - Shell, in lamps not soldered by design

C 321 - Lead wire out of tie wire
- A - Tie wire missing
- B - Lead wire out of tie wire

E 322 - Lead wire not cut
- A - Eyelet
- B - Shell

B 330 - Lead wire distorted

C 332 - Lead wires burned or corroded
- A - Outer lead wire
- B - Press lead wire
- C - Inner lead wire

D 340 - Lead wire not welded
- A - Eyelet
- B - Shell

300 - 399 LEAD WIRES

D 341 - Inverted lead wire

D 343 - Press lead wire exposed

B 350 - Dirty Mount

C 353 - Lead wire insulation omitted

C 360 - Lead wire in poor contact base shell

D 370 - Extra lead wire

D 390 - Fuse Wire Defective

400 - 499 SUPPORTS

C 400 - Disc support defective

C 401 - Support missing

C 402 - Support burned or oxidized

D 410 - Supports short-circuited

C 412 - Supports too close

C 413 - Support touches bulb

C 420 - Support loose or broken

B 421 - Support inserted correctly

B 430 - Support bent
- A - Bumped
- B - Bent

C 431 - Support poorly shaped
- A - Hook or Pigtail missing
- B - Hook or pigtail poorly shaped

470 - Extra support

13.21 DEFECT AND SHRINKAGE SYMBOLS FOR INCANDESCENT LAMPS

500 - 599 BULBS

D 500 - Bulb broken
- A - Neck or shoulder
- B - Side
- C - Bowl
- AR - Ring off at base line

D 502 - Bulb Cracked
- A - Neck or shoulder
- B - Side
- C - Bowl

D 503 - Lamp seal leaks
- A - Crack
- B - Hole inseal or imperfect sealing in.

D 513 - Lamp not tipped

D 515 - Machine stuck

D 525 - Lamp seal poor
- A - Stuck seal
- B - Cullet not cut off
- C - Mount not down in pin
- D - Cullet cracked off leaving rough edge
- E - Fine

B 534 - Bulb shape poor
- A - Flat top or side
- B - Indentations or pro-tuberances

C 537 - Bulb strained
- A - Neck
- B - Side
- C - Top

C 540 - Bulb wrong

C 541 - Light center wrong

B 543 - Overall length wrong
- A - Too long
- B - Too short

B 545 - Base cement exposed

C 546 - Lamp seal shoulder wrong

B 547 - Lamp seal shoulder distorted.

500 - 599 BULBS

B 550 - Bulb dirty

B 554 - Bulb blemished

B (
- (A - Cord or creases
- (B - Scratches or scuffing
- (C - Blisters or stones
- (D - Mold rings or twists in neck

B 556 - Material loose

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600 - 699 MOUNT GLASS

D 600 - Stem tube or flange broken

D 601 - Stem press broken

C 602 - Stem tube or flange cracked

603 - Defective Mount Weld

D 604 - Arbor broken

C 605 - Arbor cracked or chipped

B 606 - Button cracked

C 607 - Bead cracked or chipped

C 608 - Stem press cracked

609 - Tip broken

C 610 - Tip cracked

611 - Disc Loose (Metal)

D 612 - Exhaust tube broken
- A - At press
- B - Away from press

B 613 - Disc defective

C 614 - Disc tilted

D 615 - Exhaust tube closed
- A - Orifice not blown thru press
- B - Closed in glasing

13.21 DEFECT AND SHRINKAGE SYMBOLS FOR INCANDESCENT LAMPS

600 - 699 MOUNT GLASS

616 - Stem parts missing
- A - Exhaust tube
- B - Arbor
- C - Lead wires

C 617 - Lead knot exposed

618 - Cut Out Failure

619 - Improper Cut Out Failure

D 620 - Stem press leaks

B 621 - Mount eccentric
- A - Arbor & stem tube not concentric
- B - Mount not concentric with bulb
- C - Filament & stem tube not concentric with each other

C 624 - Arbor shank (metal) defective

630 - Tip poor shape
- A - Weak
- B - Sucked in
- C - Blown out

B 631 - Button poor

C 632 - Tip long
- A - Stringy
- B - Too long

633 - Stem press poor shape

634 - Tip Long (Lumiline)

600 - 699 MOUNT GLASS

C 635 - Bead faulty
- A - Poorly melted or discolored
- B - Too large or too small
- C - Loose

636 - Flange poor
- A - Irregular or cracked
- B - Rotted cold

B 640 - Mount high or low

645 - Stem tubing poor
- A - Large or small
- B - Thick or thin wall
- C - Cracked

648 - Exhaust tube crooked
- A - Bent
- B - Not concentric

B 651 - Button discolored

B 652 - Stem press discolored

653 - Metal in stem tube

B 654 - Cement in stem tube

B 655 - Stem tube dirty

C 657 - Arbor orifice defective
- A - Too small
- B - Closed

13.21 DEFECT AND SHRINKAGE SYMBOLS FOR INCANDESCENT LAMPS

700 - 799 BASES

D 700 - Base Inoperative

B 701 - Base damaged
- A - Split or punctured
- B - Eyelet or pin loose
- C - Out of round or crushed
- D - Threads distorted
- E - Base insulation broken

D 703 - Lamp inoperative cause unknown

D 704 - Solder in excess

C 709 - Short circuit or arc between contacts

E 710 - Base short-circuited

E 711 - Base loose

C 712 - Base cement deficient

C 713 - Base turned

714 - Base torn

B 721 - Soldering poor
- A - Eyelet
- B - Shell

B 723 - Bulb eccentric or base crooked

D 724 - Soldering wrong

C 740 - Base wrong

C 741 - T10 base clip position wrong

B 750 - Base dirty

B 751 - Base tarnished

800 - 899 FINISH

C 801 - Marking missing

D 803 - Lamp missing

B 830 - Marking poor

B 831 - Marking misplaced

B 832 - Diffusing coating poor

C 834 - Diffusing coating improperly located

B 835 - Frosting burned clear

C 840 - Marking wrong

NOTES ON SHRINKAGE CLASSIFICATIONS

104	Gassy Lamp	Evidenced by glow test, or by blue glow when lamp is lighted. Gassy lamps caused by oil or other foreign material in lamp will be included under defect 104.
105	Lamp not flashed	Lamps which burn out due to improper flashing will be included in this defect. This may be due to poor contact in flashing, wrong setting of rheostat, uncut lead wires short-circuiting the lamps during part of flashing.
106	No gas or wrong gas	Gas-filled lamps having excessively low gas pressure will be included under this defect.
204	Filament burned out	Where cause of burnout can be located, such as cracked bulb, press, or stem tube, or leaky tip, classify the shrinkage under defect causing burnout.
233	Filament wrong	Includes mixed filaments, coils, or mounts, but does not include mixed lamps, which are classified under 840.
300	Lead wire broken	In lamps with broken lead wires caused by the press lead not being covered by the glass will be classified under defect 343 -- Press Lead Exposed.
312	Lead wires too close	Lead wires too close to the exhaust tube orifice, which may cause a cracked stem press, will be classified under 312.

NOTES ON SHRINKAGE CLASSIFICATIONS - (CONTD.)

330	Lead wire distorted	Bumped mounts in which the lead wires are out of position will be included in this defect.
332	Lead wires burned or corroded off	Lead wires burned off or corroded off will be classified under defect 300--Lead Wire Broken.
343	Press lead exposed	See note under defect 300 Lead Wire Broken.
430	Support bent	Bumped mounts in which the supports are bent out of position, but not the lead wires will be classified under this defect.
431	Support poorly shaped	Failure to form a hook or poorly formed hooks or pigtails will be included under defect 431. Broken hooks or pigtails will be included under defect 420. -- Support Broken.
500	Bulb broken	A bulb cracked or broken with some of glass out of position. Includes bulbs or lamps.
502	Bulb cracked	A bulb checked or cracked with none of the glass out of position. Includes bulbs or lamps.
513	Lamp not tipped	Includes lamps pulled out of exhaust rubbers, or partially tipped.
556	Material loose	Pieces of glass loose or fused to the bulb larger than 50 sq. mm. will be included under defect 502. Less than 50 sq. mm. classify under defect 556.

NOTES ON SHRINKAGE CLASSIFICATIONS - (CONTD.)

600	Stem tube or flange broken	When stem tube cracks and allows a press lead to be exposed or leaves a hole in stem shoulder, classify under defect 645-- Stem Tubing Poor.

13.22 SAMPLING PROCEDURES AND TABLES

MIL-STD-105D is universally accepted as a sampling standard for incandescent lamps.

SYMBOLS AND NOTATIONS

Symbols and notes used in this guide are as follows:

Ac	Acceptance number
AOQ	Average Outgoing Quality
AOQL	Average Outgoing Quality Limit
AQL	Acceptable Quality Level
	Consumer's risk
c	Acceptance number
DPU	Defects per hundred units
LQ	Limiting Quality
N	Lot size
n	Sample size
Pa	Probability of acceptance
PD	Percent defective
Re	Rejection number

When AQL's are specified for major and minor defectives, the following rules shall govern: A sample unit containing one or more major defects shall be classified a major defective; a sample unit containing one or more minor defects shall be classified a minor defective; a sample unit containing one or more major defects and one or more minor defects shall be classified (scored) as a major defective and a minor defective.

EXAMPLE:

Given: Major AQL = 2.5 PD

Minor AQL = 4.0 PD

A sample unit was found to contain a major defect (broken weld) and a minor defect (paint run).

This sample unit shall be scored once as a major defective and once as a minor defective.

SAMPLING PLAN.

A sampling plan indicates the number of units of product from each lot or batch which are to be inspected (sample size or series of sample sizes) and the criteria for determining the acceptability of the lot or batch (acceptance and rejection numbers).

INSPECTION LEVEL.

The inspection level determines the relationship between the lot or batch size and the sample size. Unless otherwise specified, Inspection Level II will be used. However, Inspection Level I may be specified when less discrimination is needed, or Level III may be specified for greater discrimination.

CODE LETTERS.

Sample sizes are designated by code letters. Table I shall be used to find the applicable code letter for the particular lot or batch size and the prescribed inspection level.

13.22 SAMPLING PROCEDURES AND TABLES - (CONTD.)

SINGLE SAMPLING PLAN.

The number of sample units inspected shall be equal to the sample size given by the plan. If the number of defectives found in the sample is equal to or less than the acceptance number, the lot or batch shall be considered acceptable. If the number of defectives is equal to or greater than the rejection number, the lot or batch shall be rejected.

DOUBLE SAMPLING PLAN.

The number of sample units inspected shall be equal to the first sample size given by the plan. If the number of defectives found in the first sample is equal to or less than the first acceptance number, the lot or batch shall be considered acceptable. If the number of defectives found in the first sample is equal to or greater than the first rejection number, the lot or batch shall be rejected. If the number of defectives found in the first sample is between the first acceptance and rejection numbers, a second sample of the size given by the plan shall be inspected. The number of defectives found in the first and second samples shall be accumulated. If the cumulative number of defectives is equal to or less than the second acceptance number, the lot or batch shall be considered acceptable. If the cumulative number of defectives is equal to or greater than the second rejection number, the lot or batch shall be rejected.

TABLE I -- SAMPLE SIZE CODE LETTERS

LOT OR BATCH SIZE			GENERAL INSPECTION LEVELS		
			I	II	III
2	to	8	A	A	B
9	to	15	A	B	C
16	to	25	B	C	D
26	to	50	C	D	E
51	to	90	C	E	F
91	to	150	D	F	G
151	to	280	E	G	H
281	to	500	F	H	J
501	to	1200	G	J	K
1201	to	3200	H	K	L
3201	to	10000	J	L	M
10001	to	35000	K	M	N
35001	to	150000	L	N	P
150001	to	500000	M	P	Q
500001	and	over	N	Q	R

SINGLE
NORMAL

TABLE II-A — *Single sampling plans for normal inspection (Master table)*

Sample size code letter	Sample size	Acceptable Quality Levels (normal inspection)																									
		0.010	0.015	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15	25	40	65	100	150	250	400	650	1000
		Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
A	2	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↓	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31
B	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45
C	5	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑
D	8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑	↑
E	13	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	30 31	44 45	↑	↑	↑
F	20	↓	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑
G	32	↓	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑
H	50	↓	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑
J	80	↓	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑
K	125	↓	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
L	200	↓	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
M	315	↓	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
N	500	↓	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
P	800	↓	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
Q	1250	0 1	↑	↓	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
R	2000	↑	↑	1 2	2 3	3 4	5 6	7 8	10 11	14 15	21 22	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑

↓ = Use first sampling plan below arrow. If sample size equals, or exceeds, lot or batch size, do 100 percent inspection.

↑ = Use first sampling plan above arrow.

Ac = Acceptance number.

Re = Rejection number.

TABLE III-A—Double sampling plans for normal inspection (Master table)

Sample size code letter	Sample	Sample size	Cumulative sample size	Acceptable Quality Levels (normal inspection)																									
				0.010	0.015	0.025	0.040	0.065	0.10	0.15	0.25	0.40	0.65	1.0	1.5	2.5	4.0	6.5	10	15	25	40	65	100	150	250	400	650	1000
				Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re	Ac Re
A				↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↓	↓	*	*	*	*	*	*	*	*	*
B	First	2	2	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	17 22	25 31
	Second	2	4																	1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27	37 38	56 57
C	First	3	3	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	17 22	25 31	↑
	Second	3	6																1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27	37 38	56 57	
D	First	5	5	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	17 22	25 31	↑	↑
	Second	5	10															1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27	37 38	56 57		
E	First	8	8	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	17 22	25 31	↑	↑	↑
	Second	8	16														1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27	37 38	56 57			
F	First	13	13	↓	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑
	Second	13	26													1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27						
G	First	20	20	↓	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑
	Second	20	40											1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27								
H	First	32	32	↓	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑
	Second	32	64											1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27								
J	First	50	50	↓	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	50	100									1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27										
K	First	80	80	↓	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	80	160								1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27											
L	First	125	125	↓	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	125	250							1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27												
M	First	200	200	↓	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	200	400							1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27												
N	First	315	315	↓	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	315	630						1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27													
P	First	500	500	↓	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	500	1000					1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27														
Q	First	800	800	*	↑	↓	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	800	1600				1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27															
R	First	1250	1250	↑	↑	0 2	0 3	1 4	2 5	3 7	5 9	7 11	11 16	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑
	Second	1250	2500			1 2	3 4	4 5	6 7	8 9	12 13	18 19	26 27																

↓ = Use first sampling plan below arrow. If sample size equals or exceeds lot or batch size, do 100 percent inspection

↑ = Use first sampling plan above arrow

Ac = Acceptance number

Re = Rejection number

* = Use corresponding single sampling plan (or alternatively, use double sampling plan below, where available).

DOUBLE NORMAL

13.22 SAMPLING PROCEDURES AND TABLES - (CONTD.)

The choice of the level of inspection depends on how close the estimated process average is to the A.Q.L. Thus the scheme adopts the sensible approach of taking into account the quality of recent batches. If the production line turns out a bad batch then it is sensible to take larger samples than usual. On the other hand, if the process has been producing good batches for a long period then reduced sampling can be employed. The sampling scheme is chosen in such a way that the producer's risk is much smaller for large lots than for small lots. The reason for this is that it is much more serious to reject a large batch when it is 'good' than it is to reject a small batch.

The following is a copy of the double sampling inspection system from a GLS lamp plant. Note that the AQL varies considerably for Vitals, Majors and Minors. It is common to design inspection Report work sheets for specific applications and sampling plans.

DOUBLE SAMPLING INSPECTION SYSTEM

1. A Double Sampling Inspection System according to Mil. Std. 105D is applied to the finished product.
2. Remove from the pallets in the LOT the number of cases necessary to inspect the required sample size. Choose as random a sample as possible. Do NOT inspect more than 50 lamps from any one case.

GTE Sylvania Company P ivate

DOUBLE SAMPLING INSPECTION SYSTEM - (CONTD.)

3. Record the Tote Production Code from the Tote ticket.

4. Inspect the required lamps for Vital, Major, and Minor defects as defined in Spec. 2E0404-101 to 840.

5. Record in the spaces provided the number of lamps inspected from each case. When the TOTAL sample size has been inspected, circle the sample size number of the Packed Stock Inspection Worksheet.

6. According to the inspection results of the first sample, the LOT will be either ACCEPTED, REJECTED, OR SUBMITTED TO A SECOND SAMPLE INSPECTION.

7. When it becomes necessary to inspect a second sample, the results of this inspection will dictate the ACCEPTANCE OR REJECTION of the LOT.

8. All rejected LOTS will be 100% reworked and resubmitted to this sampling plan.

LOT SIZE	SAMPLE SIZE	VITAL 0.65 AQL		MAJOR 1.5 AQL		MINOR 4.0 AQL	
		AC	RE	AC	RE	AC	RE
1,201 - 3,200	n_1 - 80	0	3	2	5	5	9
	n_2 - 80	3	4	6	7	12	13
3,201 - 10,000	n_1 -125	1	4	3	7	7	11
	n_2 -125	4	5	8	9	18	19
10,001 - 35,000	n_1 -200	2	5	5	9	11	16
	n_2 -200	6	7	12	13	26	27

n_1 = First sample

n_2 = Second sample

13.23 REFERENCE FOR ADDITIONAL IN-DEPTH INFORMATION

1. Guide for Use of Mil-STD-105D available from GSA Federal Supply Service, Washington, D.C. 20407

2. American National Standard Sampling Procedures and Tables for Inspection by Attributes available from American National Standards Institute, Inc. -- ANSI -- 21.4 -- 1971.

3. Incandescent Lamps by W. G. Matheson, GTE Sylvania, Danvers, Mass. 01923 - Chapter 18.

4. GTE Quality Control Manuals available from Quality Manager, GTE Sylvania, Danvers, Mass. 01923

14.0 TROUBLE SHOOTING

The following is a list of common problems and probable causes of problems encountered in the manufacturing and testing of incandescent lamps. Note that both U.S.A. terms and their European counterparts are used synonymously in this chapter.

Additional data on problems and solutions will be found in Chapter 6 Failure Mechanisms and Chapter 13 on Quality Assurance.

14.1 SHORT LIFE - POOR MAINTENANCE

PROBLEM	PROBABLE CAUSES
Black Lamps	Water Cycle
Sooty Leads and Supports	Low Pressure Forced Voltage too High No Getter
Yellow-Brown Lamps (Vacuum)	Excessive Phosphorous Getter
Gassy Lamps (Vacuum)	Poor Pumping Bulb Not Outgassed Glass Cracks Wire Leak
Water Cycle	See Chapter on "Failure Mechanisms"
Arcing	Dirty Filament Wire Dirty Support Wire Wrong Fill Gas Lamp Not Flashed

TROUBLE SHOOTING

14.2 FLARE-MAKING

PROBLEM	PROBABLE CAUSES
1. Chipped Flares	Bad flame annealing. Bad Handling.
2. Wavy Flares	Glass too hot when reamering. Annealing flames too hot.
3. Wrong Dimensions	Wrong machine setting.
4. Reamer/score marks	Reamering with glass too cold. Bad reamering tool. Insufficient SO_2 in combustion gas.
5. Bad Ends	Cutting knives not sharp. Cutting knives badly adjusted. Flames not adjusted properly.
6. Bad end glazing	Flame not adjusted properly.

14.3 STEM-MAKING

1. Chipped flares at ends when melting.	First flames too hot. Flares not properly end glazed.
2. Exhaust stems out of line.	Heads of machine require lining-up. Exhaust stems not sufficiently cool when transferring into Annealer causing stems to be bent by extractor.
3. Wrong dimensions.	Wrong components. Wrong machine setting.
4. Weak exhaust stems.	Faulty annealing. Stems not blown out at junction to pinch.

TROUBLE SHOOTING

14.3 STEM-MAKING - (CONTD.)

PROBLEM	PROBABLE CAUSES
5. Leaky presses.	Insufficient heat. Glass not flowing around and joining to the copper clad wires.
6. Burnt copper clad in press.	Weld locating jaws burnt away. Flames set too low so that they creep under the flares.
7. "Cold Presses"	Too little heat. "Cold Pinches" are often caused by the end of the flanges being pushed down so that they rest on the weld locating jaws. Check the position where the flanges are pushed down to see that the spacing strip is operating effectively.
8. Cracked Presses	Incorrect annealing. Glass not blown out just above pinch. Removing stems from the annealer before they have passed through the annealing cycle.
9. No hole in press	Head or heads not lined up so that the exhaust tube misses the hole blowing tube. Glass not hot enough. Flames at hole blowing position extinguished.
10. Red wires in Press.	Copper oxide not dissolved into glass - insufficient heat.

TROUBLE SHOOTING

14.3 STEM-MAKING - (CONTD.)

PROBLEM	PROBABLE CAUSES
11. Press not in center of stem	If fault is on all stems, pinch hammer mechanism should be adjusted. If fault is on individual stems, heads should be adjusted.
12. Exhaust Stem. Flare tube and rod out of alignment.	Heads require lining-up.
13. Too much strain in glass.	Bad annealing.

14.4 MOUNTING:

1. Faulty feeding-in	Exhaust tubes out of line (S.M.) Feed-in mechanism requires cleaning or adjustment.
2. Cracked studs (buttons)	Faulty flame adjustment. Getter in pot too high causing liquid to touch stud.
3. Pigtails shorting in stud.	Faulty adjustment of inserting head/heads.
4. Missing pigtails.	Molybdenum spool empty. Bad adjustment of inserting head. Molybdenum wire tangled on spool.
5. Hanging filaments	Vacuum pick-up finger blocked. Setting of vacuum finger faulty. (Check movement and position on filament drum and when delivering filament into lead-in wire hooks) Bad setting of filament trimmers on drum.

TROUBLE SHOOTING

14.4 MOUNTING - (CONTD.)

PROBLEM	PROBABLE CAUSES
6. Pigtails miss curling (straight wires)	Faulty curling head. Bad positioning of curling head. Molybdenum too high/too low - Check and adjust at inserting position.
7. Open pigtail eyes.	Faulty adjustment of leaf springs on curling elements.
8. Uneven pigtail lengths.	Faulty positioning of curling elements.
9. Filament tension faulty.	The mechanism which pushes the leading-in wires forward before curling not adjusted correctly.
10. Filament in hooks not pinched-in correctly.	Faulty adjustment of trimmers on drum. Faulty adjustment of pick-up fingers.
11. Filament not gettered.	No phosphorous in getter pot. Level of phosphorous too low in getter pot.
12. Getter not dry on filament before Transfer from machine.	Faulty positioning of heater in relation to filament. Heater not switched on or burnt out. Blower air not turned on or air pipe blocked.
13. Unloading Problems.	Exhaust tubes out of line (S.M.) Heads out of line. Mechanism requires adjustment. Mounted stem conveyor chain requires adjustment.

TROUBLE SHOOTING

14.4 MOUNTING - (CONTD.)

PROBLEM	PROBABLE CAUSES
14. Broken exhaust stems.	Weak stems (S.M.) Feed-in/ take-out mechanisms require adjustment.
15. Broken rods.	Weak rods (S.M.) Feed-in/ take-out mechanisms require adjustment. Heads out of alignment.

14.5 SEALING-IN:

PROBLEM	PROBABLE CAUSES
1. Faulty feed-in	Stems out of alignment (S.M.) Length of exhaust tube to flange too long/too short (S.M.) Mechanism faulty. Sealing-in pins not all same height.
2. Cracked bulbs	Heat applied too suddenly. Mechanical shock. On occasions inherent strain in the bulbs (for example - Colour glazed bulbs).
3. Glass blowing out in sealing Area when melting.	Insufficient clearance through center of sealing-in pins and holes in sealing track to allow the expanded air free and easy access. (Usually blocked pins and blocked holes in track). No hole in pinch (S.M.)

TROUBLE SHOOTING

14.5 SEALING-IN - (CONT.)

PROBLEM	PROBABLE CAUSES
4. Difficulty in "cutting off"	Too great an area of glass melted above the flange, or glass too hot which causes glass to flow down and thicken in the "cut-off" area. Bridge pieces set too high, not allowing the glass to thin out sufficiently. Blocked air holes in pin tops, pins not all set at the same height. "Cut-off" burners not burning properly or not set correctly. Air blowing pipe not in correct position. Check air flow.
5. "Wings" on Seals.	Insufficient heat on head distribution burners in EARLY STAGE of sealing to enable air in lamps to expand and escape. Insufficient clearance through center of sealing-in pins and holes in sealing track to allow the expanded air free and easy access. The seal should form into a concave shape when the sealing-in pin drops 2 mm. as it leaves the seal heating position. The pin not dropping 2 mm. (check that pins are free to drop easily).

TROUBLE SHOOTING

14.5 SEALING-IN - (CONTD.)

PROBLEM		PROBABLE CAUSES
5. "Wings" on Seals - (Contd.)		The glass sagging down at the seal heating position (the head in this position must make at least ½ turn, thus heating the seal evenly and preventing the glass sagging in one spot). The neck moulds set at wrong height.
6. Bad shape.		Sealing-in flames set badly. Neck moulds not set correctly and concentrically with pin tops.
7. Cracked seals.		Sharp seals: a) Pins not dropping, preventing the glass from dropping between the seal heating position and the neck mould position. b) The glass not sufficiently hot to allow it to drop.
	Bad annealing	a) Pins not dropping between the neck mould position and first annealing position. b) Annealing flames not set properly or annealing flames not lit.
	Neck moulds:	a) Score mark/marks in the mould (the moulds must be polished and free from any imperfections). b) Neck moulds not lined up correctly. Neck moulds not set at correct height.

TROUBLE SHOOTING

14.5 SEALING-IN - (CONTD.)

PROBLEM		PROBABLE CAUSES
7. Cracked seals.	Neck moulds:	c) Neck moulds not heated (flames extinguished) or not sufficiently hot).
		d) Too much air through pins when blowing glass into moulds.
	After cooling:	Faulty adjustment of air or air pipes on intermediate turret.
	Bad cut-off:	(The cullet not completely cut off). This leaves a piece on the seal after neck moulding, which, if broken off, can cause a cracked seal.
		TOP OF CULLET SPLINTERING AND GLASS CHIPS STICKING TO SEAL: BURNER NOT PROPERLY ADJUSTED.
8. Faulty bulb stamping:		If the stamp is not in the center of the bulb, this is caused by bad adjustment of the stamping machine (bulb centraliser and top plate), or by the rubber stamp not being positioned in the center of the pad. If the impression is not clear, this is caused by a poor stamp or by poor inking (check the ink and the inking mechanism).
9. Stamps not burnt in:		Faulty adjustment of burners.
10. Clear tops on pearl lamps		Top burners too hot.

TROUBLE SHOOTING

14.5 SEALING-IN - (CONTD.)

PROBLEM	PROBABLE CAUSES
11. Lamps too hot/too cold when transferred to pump:	Faulty adjustment of heat distribution burners. (See also POINT 5.)
12. Burnt wires:	Faulty stem feeding into sealing pins. Check mechanism.
13. Pick up and feeding of bulbs into machine:	Mechanism requires adjusting.
14. Poor Burner performance:	Burners dirty. Filters dirty. Injectors dirty. Gas/Air pressure low. Oxygen pressure low. Blocked oxygen capillary.
15. Holes in seals:	Cracked/chipped flanges. Too severe heat in early stages of sealing. Burners set too high.
16. Necks too thin:	Bridge pieces set too low, causing excessive stretch of glass.
17. Knocked Mounts:	Mount diameter too big (M.M.) Bulb not centralized. Mount not concentric (S.M. or M.M.).
18. Wrong Mounts in lamps:	Wrong filaments mounted (M.M.). Failure to check rating before starting production.

14.6 EXHAUST MACHINE:

1. Broken exhaust tubes	Weak stems (S.M.) "Scissors" mechanism requires centralizing. Intermediate transfer requires adjustment (check vacuum cups and vacuum on/off timing)

TROUBLE SHOOTING

14.6 EXHAUST MACHINE - (CONTD.)

PROBLEM	PROBABLE CAUSES
1. Broken exhaust tubes	Pump cradles out of alignment. Blocked or partially blocked pump heads.
2. Burnt wires:	Hole in "scissors" too big. (Allows leading-in wires to slip through). "Scissors" mechanism (wire spreader) not timed correctly. Deflector plates on pump cradles require adjustment. Sealing-off burners require adjustment.
3. Blown out Tips	Sealing-off burners too hot. Argon escape, capillary blocked.
4. Sucked-in Tips (Gas-filled lamps):	Blocked pump head (usually pieces of broken exhaust tube). Leak detector not operating properly (closing off good lamps).
5. Too long Tips	Bad burner adjustment. Very long Tips caused by exhaust tube being held up by broken glass in pump heads.
6. Leaky Lamps:	Cracked bulb, hole in seal, cracked seal (S.I.), cracked pinch, leaky pinch, cold pinch (S.M.)
7. Faulty Pumping:	Poor vacuum connection, cracked dust trap, hole in rubber connections, bad valve plates, poor performance of mechanical pumps, compression rubbers in heads not sufficiently gripping exhaust tubes (can be rectified by adjusting head closing levers). Poor compression rubbers, failure of leak detector to

TROUBLE SHOOTING

14.6 EXHAUST MACHINE - (CONT.)

PROBLEM	PROBABLE CAUSES
7. Faulty Pumping	isolate head with leaky lamp. Dirty pumping system. NOTE: A LEAKY LAMP NOT ISOLATED BY THE LEAK DETECTOR CAN SPOIL THE VACUUM ON AT LEAST FIVE LAMPS BEFORE AND FIVE LAMPS AFTER THE LEAKY POSITION. Means of checking - High Frequency Coil.
8. Faulty gas filling:	Same causes as for faulty pumping. In addition there are other causes - Leaky connection on the Nitrogen Flushing and Argon filling lines. Leaks on the high pressure side (cylinders and connections) Dirty gas lines. P_2O_5 driers require renewing and faulty cylinders of gas. Check with High Frequency Coil.
9. Phosphorous flashing (Vacuum lamps and gas-filled lamps where oven is used.)	Oven temperature too high.
10. Gas Pressure too low:	Cooling not sufficient.
11. Good lamps clipped off:	Faulty leak detector (May be an electrical fault). Vacuum pipes blocked.
12. Leaky lamps and empty heads not clipped off:	Faulty leak detector (May be an electrical fault). Vacuum pipes blocked.

TROUBLE SHOOTING

14.6 EXHAUST MACHINE - (CONTD.)

PROBLEM	PROBABLE CAUSES
13. Cracked Tips: (Vacuum lamps)	Very accurate flame setting is required. Cracked Tips can be caused by: (a) Excessive "sucking-in" of the glass. (b) By thick glass at the end of the Tip resulting from "melting back" too much the "sealed off" capillary end. Consistent Tips can be achieved from every head by checking to see that every pump cradle is of the same length relative to the "tipping-off" track and of the same height above the machine turret. The cradles must be free to move easily up and down in the cradle supports.

14.7 BASING

1. Crooked Bases	Bad shape and badly moulded seals (S.I.) Capping machine dies dirty, preventing the caps from seating properly. Worn capping dies. Lamps not fed into machine properly.
2. Loose Bases:	Baking temperature too low. Capping paste mixture faulty. Too little capping paste. Pasted caps standing for too long a time before use. If the caps are loosened on ejection from the machine, check cooling and ejection mechanism. If the caps are loosened

TROUBLE SHOOTING

14.7 BASING - (CONT.)

PROBLEM	PROBABLE CAUSES
2. Loose Bases:	during the wire cutting process (Usually side wire cutting on E.S. caps) - check mechanism.
3. Lead-in wires not cut:	Lead-in wire/wires trapped in capping die. Lead-in wires bent down too much (these are faults in operation). Wire straightening device not working properly. Wires bent by the air-switches. Cutting knives badly set. Cutting knives blunt.
4. Unsoldered:	Capping paste on contacts. Poor fluxing. Bad flame adjustment. Faulty position of solder.
5. Solder down Flare	Cap too hot. Position of solder. Fault with fluxing. Fault with the flux (the flux has de-emulsified). To prevent de-emulsification the flux in the bottle must be kept cool.
6. Crossed wires. Close wires:	Fault in operation.
7. Lamps not lighting on ageing:	Faulty switches. Lead-in wires (bent wires).
8. Lamp flashing on ageing:	Wrong voltage. Crossed lead-in wires.
9. Basing Cement around outside of cap and seal:	Check "cut-off" of Basing Cement on filling machine.

TROUBLE SHOOTING

14.7 BASING - (CONT.)

	PROBLEM	PROBABLE CAUSES
10.	Basing Cement down flare tube:	Viscosity of capping paste too thin. Excess capping paste.
11.	Bent or loose Base pins:	Check all mechanical devices which handle the caps. The caps tight in capping dies. (Dirty with baked capping paste).
12.	Solder connecting contact with shell of cap:	Check fluxing and soldering mechanisms. Excess flux.
13.	Lead-in wire touching inside of base.	Wire not pulled up properly by wire straightening device.

NOTE:

F	=	Fault in Flange-Making.
S.M.	=	Fault in Stem Making.
M.M.	=	Fault in Mounting.
S.I.	=	Fault in Sealing-in.

14.8 WATER VAPOUR

The presence of WATER VAPOUR in an incandescent lamp can have a disastrous effect on the life of the lamp because it rapidly increases the evaporation of the tungsten filament.

Once it is inside the pumped lamp the chemical reaction between the water vapour and the tungsten filament is a cycling process -

14.8 WATER VAPOUR

WATER		TUNGSTEN		TUNGSTEN OXIDE		FREE HYDROGEN	
H_2O	+	W	$\longrightarrow$	WO	+	H_2	$\longrightarrow$

$$W + H_2O \longrightarrow WO + H_2 \longrightarrow$$

$$W + H_2O - - - - -$$

The tungsten which is rapidly evaporated from the filament is deposited on the inside bulb walls.

14.8.1 CHECK ON THE PRESENCE OF WATER VAPOUR

Burn a pumped lamp at 120% of Rated Voltage for 1 hour, burning cap-up.

The molybdenum supports should be perfectly clean and bright. If the molybdenum supports are darkened about 2 - 4 mms. from the eyes this is an indication of the presence of water vapour in the lamp and the degree of darkening is an indication of the extent of water vapour attack.

Regular hourly checks must be made on lamps from each production group.

14.8.2 WHERE DOES THE WATER VAPOUR COME FROM?

1. From the Nitrogen and Argon

   The gas manufacturers do not guarantee that the gas is 100% water vapour free and experiments have shown that the water

14.8.2 WHERE DOES THE WATER VAPOUR COME FROM - (CONT.)

vapour content appears to increase as the pressure inside the cylinder decreases.

The phosphorous Pentoxide driers (P_2O_5) readily absorb any water vapour as the gas passes through them, provided that the P_2O_5 driers are in good condition.

2. From the gas lines not being absolutely vacuum tight.

3. From a small leak on the High Pressure side of the cylinders where air is injected into the gas system.

4. Inside Silica-Oxide Coated Lamps (Whitelight lamps)

   The Silica Oxide which is deposited on the inside of the bulbs is obtained by burning Ethyl Silicate and Oxygen (see White-lighting process). The Silica Oxide absorbs water vapour from the atmosphere very readily, and for this reason, processed bulbs must be sealed-in and pumped within two hours of processing.

   It is permissible to hold up to 500 - 600 bulbs over the week-end period, provided that they are stored in a temperature (70°F) and humidity controlled room.

5. Delay period between Sealing-in and Pumping.

   There should be no delay time between sealing-in and pumping. It is a very bad practice to remove lamps from the sealing-in machine and hold them for some time before feeding them into the pump.

14.8.2 WHERE DOES THE WATER VAPOUR COME FROM - (CONT.)

5. This is especially disastrous when "cold pumping" lamps on the Sealex groups.
   The temperature of the lamps when leaving the sealing-in machine is of vital importance.

6. Lamp components (Stems - Mounted Stems)
   Stems should be mounted and sealed-in with as little delay as possible.
   It is necessary to hold a buffer stock of stems and mounted stems, but this stock must be maintained at a minimum level and the stems should be sealed into lamps within 24 hours of manufacture.

14.8.3 ELIMINATION OF WATER CYCLE

Refer to Chapter 6 for Additional data on Water Cycle Causes and Remedys

14.9 TROUBLE SHOOTING THE SYLVANIA AUTOMOUNT

(See 10.9 - Chapter 10)

15.0 GENERAL

15.1 CONVERSIONS

15.1.1

U. S. A. TERM	INTERNATIONAL TERM
Dumet	Copper Clad
Line Voltage	Mains Voltage
Voltage	Tension
Coil	Spiral
Mandrel	Core
Base	Caps
Basing Cement	Capping Paste
Flare	Flange
Press	Pinch
Base Up	Pendant Position or Cap Up
Nickel	Vernko
Tip	Pip
Fire Polish	Glaze
Support Loop	Pigtail
Cold Press	Cold Pinch
Screw Base	Edison Cap
Bayonet Base	Swan Cap
Gas Mixer	Injectors
Pinch Rubber Closed	Clipped Off
Borated	Boraxed
Craze	Crizzle
CC-9	Wreath Filament
Trimmer	Centering Device

GENERAL

	U.S.A. MEASUREMENT TERM	EUROPEAN MEASUREMENT TERM
15.1.2.1	PRESSURE	
	Torr	Pascal (Pa)
	1 Torr = 133.3 Pa	
	1 Pa = 0.0075 Torr	
	Micron	Pascal (Pa)
	1 Micron = .1333 Pa	
	1 Pa = 7.5 Microns (M)	
	One Atmosphere = 750 mm Hg	
	750 Torr	
	10^5 Pascals	
	1 Bar	
15.1.2.2	WIRE DIAMETER	
	Mils	Microns
	one Mil = 25.4 Microns	
	one Micron = 0.03937 Mils	
15.1.2.3	WIRE WEIGHT (TUNGSTEN)	
	Mg/200 mm	Mg/200 mm
	Mg/200 = 1.943 (Wire diameter in Mils)^2	Mg/200 = 0.003 (Wire dia. in μM)^2
15.1.2.4	LEAD WIRE DIAMETER	
	Mils	Millimeters
	One Mil = 0.0254 mm	
	One mm = 39.37 mils	

15.1.2

GENERAL

U.S.A. MEASUREMENT TERM	EUROPEAN MEASUREMENT TERM

15.1.2.5 BULB DIAMETER

Eighths of an Inch — Millimeters

A-19 Bulb Diameter is $\frac{19}{8}$ = 2.375 inches — 60.325 mm

1/8 inch = 3.175 mm

1 mm = 0.040 inches

15.1.2.6 TORQUE

inch-pounds — Newton meters (Nm)

one inch-pound = 1.129848×10^{-1} Nm

one Newton meter = 8.85 inch pounds

Foot-pounds — Newton meters (Nm)

one foot-pound = 1.355818 Nm

one Nm = 0.73756 foot-pounds

15.2 LIGHTING UNITS.

CANDELA The illuminating power of a light source in a given direction is expressed in CANDELAS. The Candela is the standard international unit (SI = Systeme Internationale d' Unite).

CANDLE The unit of illuminating power which was used in Gt. Britain. The Candle is the illuminating power of a Sperm Oil candle burning at the rate of 120 grains per hour.

LUMEN This is the unit of LIGHT FLUX. It is the amount of light contained in one steradian from a light source of one CANDELA in all directions.

15.2 LIGHTING UNITS.

LUX This is the illumination produced by 1 LUMEN over an area of 1 Square Metre. The non-metric equivalent LUMENS PER SQUARE FOOT is still used in this country, and is called a FOOT-CANDLE in America (1 FOOT CANDLE = 10 LUX approximately).

CANDELA PER SQUARE METRE is the unit of measured brightness (called LUMINANCE).

APOSTILB One Lumen emitted per square metre.

CANDELA PER SQUARE FOOT: The imperial unit of measured brightness (LUMINANCE).

FOOT-LAMBERT. The imperial unit of one lumen emitted per square foot of surface area.

LUMINANCE. The light reflected FROM a surface or emitted by it.

ILLUMINANCE The measure of light FALLING-ON a surface.

Example 1: A sheet of white paper having a REFLECTANCE of 75% has an illuminance of 100 LUX. ITS LUMINANCE WILL BE 75% x 100 APOSTILBS = 75.

LUMINANCE. The measured brightness of a surface.

LUMINOSITY The APPARENT brightness.

Example: The LUMINANCE of a lamp burning during the day or night is the same, but the LUMINOSITY burning in daylight is very low and burning at night could be very high.

EFFICACY This is the LUMINOUS EFFICIENCY of a Lighting Source expressed in LUMENS PER WATT consumed (usually written L/W).

THE LANGUAGE -- SOME TERMS DEFINED

Aberration - An effect caused by a poorly designed optical system which causes the image to be without sharp definition or to have colored fringes. Aberration is divided into two forms. Spherical aberration is when edges are overlapped or not sharply defined. Chromatic aberration is when the image is bordered by colored light.

Absorption - The loss of light caused by its passing through a medium or striking a surface. The amount of light lost or absorbed is a percentage of the total light and is known as the absorption factor.

Accommodation - The adjustment of the lens of the eye for seeing objects at differing distances.

Actinic - Defines the quality of light which activates the chemical emulsion on a photographic plate or film.

Adaption - The adjustment of the iris to the intensity of lighting of the field of view.

Adapter - A device used in conjunction with incandescent lamp sockets in order to accommodate differently based lamps. These are only used for temporary installations.

After Image - The retained image impressed on the retina of the eye by viewing a very bright source for a period of time. The color of the image is complementary to that of the object that has been viewed. The image persists for some time and prevents perception of detail and, if severe, obscures all else. Avoid direct exposure to such hazards.

Ageing - The process of seasoning new lamps to achieve stable operating conditions; usually only required for measurement purposes. The process generally consists of over wattage operation for a prescribed period.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Alignment - The exact arrangement of parts or elements with respect to an axis.

Angle of Incidence - The angle which a beam of light makes with a perpendicular to the surface it strikes.

Angle of Reflectance - The angle which a light beam makes with a perpendicular to a smooth reflecting surface on leaving that surface.

Angstrom Unit A - A unit of length for expressing the wavelength of light.

1 Angstrom unit = 10^{-7} millimeters

1 Angstrom unit = 10^{-4} microns

1 Angstrom unit = 10^{-1} millimicrons

1 Angstrom unit = 10^{-1} nanometers

Modern practice dictates the use of the term 'Nanometers' as the acceptable measurement unit for the wavelength of light.

Arc Lamp - A lamp candle in which the light is produced by an electrical current flowing across a gap between two electrodes. Some of the electrode material is vaporized to form the arc stream. Among the most commonly used forms is the open and closed carbon arc types. The modern enclosed sources are classified as arc discharge types. See mercury metal halide and sodium light sources.

Astigmatism - A cylindrical variation in a lens or in the eye which causes rays of light to be focused at different points, often causing indistinct vision and imperfect images.

Asymmetric Distribution - Condition existing when the light from a source is emphasized in one or more directions at the expense of other directions.

Axis - An imaginary straight line which is the center of symmetry.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Base - Generally a metallic and insulator assembly attached to the light source and providing support as well as a means to connect it to an electrical circuit.

Beam - A beam of light may be cylindrical as a cone or in other cases it is configured by a lens to shapes other than circular.

Beam Spread - The divergence of a beam measured in degrees.

Black Body - A theoretic object that is assumed to absorb all radiations falling on it and, when raised in temperature, emits radiations according to Planck's radiation law.

Brightness - Any object emitting or reflecting light is said to be bright if visible. The term bright is purely qualitative. A scale of brightness is required for comparison purposes.

Bulb - A bulb is a glass container of special shape or size in which an incandescent filament type source is placed.

Candle - The word 'candle' refers to the International candle: a unit of luminous intensity resulting from international agreements. Special incandescent lamps are used to maintain the agreed standard.

Carbon Lamp - An incandescent source utilizing an homogeneous carbon thread as a filament. Nowadays they are only used as infrared sources.

Characteristic Curve - A characteristic curve expresses a relationship between two variables of a light source, e.g. Live vs. Applied Voltage.

Coiled Filament - A coiled filament is the result of winding a straight wire in the form of a helix prior to mounting in a lamp.

Coiled-Coil Filament - A coiled-coil filament is the result of the winding of a coiled filament into a second helix before mounting in a lamp. The first helix is known as the primary coil and the second helix becomes the secondary coil.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Concentrated Filament - A concentrated filament is one which is formed in such a manner that individual filament sections are located close to each other to produce an intense area of light. The sections may be of wire, coils or coiled coils.

Degrees Kelvin - Degrees Kelvin is the Absolute Temperature Scale. It is equal to the Centigrade Scale plus 273.1°. The temperature of an incandescent lamp is expressed in Degrees Kelvin.

Depreciation - A gradual diminution of light output from a lamp. It is generally considered as the change inside the lamp rather than accumulated dirt on the outside; e.g. blackening due to tungsten evaporation.

Design Voltage - The particular voltage at which a lamp will deliver its rated lumen output for its rated life.

Diffraction - Diffraction is a modification which light undergoes, as in passing by the edges of opaque bodies or through narrow slits, in which the rays seem to be deflected, producing fringes of parallel light and dark or colored bands.

Diffusion - The scattering of light rays, e.g. inside frosting of a bulb diffuses the light.

Efficiency of a Source - Efficiency of a lamp is expressed as the ratio of the total luminous flux to the total power consumed.

Etching - The marking of a lamp in a distinguishing manner.

Extended Source - An extended light source is one whose dimensions preclude it being a so-called point source. In truth, practically all lamps are extended light sources. Radiations from them respond to modified mathematical formulas and obey varied geometric distributions.

Filament - A filament is a conductively continuous light giving element which incandesces due to the passage of current through it.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Fixture - A fixture is essentially a lamp-holding device designed for lighting purposes.

Flame Tint - The color of a lamp bulb coating which gives the impression of a kerosene oil source.

Flasher - An electro-mechanical device for switching incandescent lamp on and off at regular intervals, e.g. traffic signals and signs.

Flashing - A term describing a process in the manufacture of lamps when each lamp is subjected to a programmed light-up at controlled voltages to activate certain chemical and metallurgical changes within the lamp, thus preparing it for its ultimate use.

Fluorescence - The production of light from activated source materials by their exposure to ultraviolet radiations, e.g. the low pressure mercury arc produces ultraviolet radiations which are the basis for the fluorescent lamp.

Flux - As applied to lighting, flux may be considered as the intensity of a source in lumens divided by the area over which the light is distributed.

Focus - The adjustment of optical elements, such as lenses, to produce an image or a desired amount of light. The point where the image is formed is known as the principal focus of the lens.

Focal Point - The focal point of a lens or a converging mirror is the point in space in front of it at which all incident parallel light rays are converged.

Focal Length - The focal length is defined as the distance from the optical center of the lens or reflector to the focal point or real focus. Focal length of a mirror is the distance along the axis from the reflector to the focal point.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Gas Filled Lamps - Gas filled incandescent lamps are those types which have an inert gas, such as argon, in the envelope. These are known as Type Clamps.

Getters - Getters are chemical substances introduced into lamps during the manufacturing process to improve their performance during life. These chemicals remove certain elements and compounds, such as oxygen, hydrogen and water vapour. The activation of the getter may bring about a chemical reaction or absorption or both. Some getters continue to perform throughout the lamp life.

Glass - Glass describes a smooth surface which tends to reflect light in a specular manner.

Hue - The property of color by which various spectral regions are distinguished.

Illumination - The visual sensation produced when radiant energy within the wavelength range between 380-780 nanometers falls upon a surface and is of sufficient intensity and duration so that it is recognized by the eye. Light emitted from a source is excluded by this definition.

Incandescence - Incandescence is when an object is raised in temperature so that it glows and thus emits visible radiation. At low temperature the color composition is in the red or longer wave length end of the spectrum, and as the temperature increases the color shifts to the blue or shorter wave length end of the spectrum. The radiations from an incandescent lamp filament when subjected to increasing voltage, changes color as its temperature increases.

Infrared Radiations - Infrared radiations are those longer wave radiations immediately beyond the visible spectrum, that is, beyond 780 nanometers, which are evidenced as radiant heat. Filament incandescent lamps have a larger portion (85-95%) of their total radiations in the infrared.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Inside Frost - The chemical etching of the inside surface of a lamp bulb. Its purpose is to diffuse the light, thereby reducing glare.

Lamp - The term applied to the finished incandescent light source ready for use in a lamp housing or lamp holding mechanism.

Large Lamps - Large lamps are generally classified as those types larger in wattage than 200 watts, used principally in industrial and commercial applications. Excluded are photographic and host halogen types.

Life of Lamp - The life of a lamp is the average laboratory life of a given design when burned under conditions specified. The test specifications for many types are defined by the Bureau of Standards. In the case of the incandescent lamp, efficiency and life is determined by filament temperature. The test lot must contain a statistically significant number of lamps.

Life Test (Normal) - Life testing consists of burning at rated volts a sufficient number of lamps in designated lamp holders until all lamps have failed. From the results obtained, one can judge if the lamp life performance is satisfactory.

Light Center Length - The light center length is generally considered that distance from bottom contact on the base to the center of the filament. This feature is important when lamps are used in optical systems.

Light - For our purposes, light is the visually evaluated radiant energy.

Light Source - Any object or surface that emits light, naturally or artificially, directly or through reflection.

Lumen - The lumen is the unit of luminous flux. It is equal to the flux through a unit solid angle (steradian), from a uniform point source of one candela (candle).

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Luminous Flux - The time rate of flow of light.

North Sky Light - North sky light is diffusely reflected light from the sky through a single window exposed to the north. Its spectral composition contains more blue than direct sunlight. Its constancy of spectral composition permits its use as a standard for color matching.

Optic System - An optic system consists of several elements such as lenses, mirrors, prisms, arranged to perform a desired light function.

Over-all Length - The distance from the end of an incandescent lamp bulb to the tip of the base contact.

Over Voltage - Over voltage is a voltage impressed across a lamp which is in excess of the lamp's designed voltage. Over voltages increase light output and diminish lamp life. Under voltage acts in the opposite manner.

Parabolic Reflector - A parabolic reflector has its reflecting surface in the form of a paraboloid. Light reflected from the focal point of such a device is essentially projected in a direction parallel to the principal axis of the reflector.

Photometer - An instrument for measuring light intensities. They generally use standard lamps for calibration and results obtained are based on comparison of the unknown light intensity to that of the calibrated standard.

Point Source - A light source having no dimensions. No such source exists except as a theoretical device for mathematical calculations. Complex optical calculations are required for all practical source configurations.

Lumens per Watt - Lumens per watt is the term used to denote the efficiency of a lamp. In incandescent lamps all the power supplied is included as there is no auxiliary ballast to consume energy. Initial lumens per watt are those measured at the beginning of life.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Luminescence - The emissions of light caused by a change in the nature of a luminous material when acted upon by certain radiations.

Lux - The lux is a unit of illumination using the metric system. It is the uniform illumination of a square meter of surface by a lumen.

Matte Surface - Matte surfaces completely scatter all light falling upon it. The surface appears equally bright from all angles.

Micron - A unit of length equal to 1 x 10^{-3} millimeters.

Miniature Lamp - Miniature lamps broadly include those lamps which are of small wattage and have other than medium, mogul, candelabra or bayonet candelabra bases.

Monochromatic Light - Monochromatic light has a single spectral hue of very narrow range of wavelength, ideally a single wavelength or frequency.

Multiple Lamp - Multiple lamps are designed to operate in parallel at constant voltage.

Power Consumption - Power consumption is the quantity of electrical energy in watts required to operate a lamp or device multiplied by the hours used. This amount is known as the kilowatt hour consumption.

Primary Standard - The primary standard is one which establishes the unit of light and from which all other standards are calibrated.

Quality of Lamps - Quality of lamps is mainly expressed in three terms -- efficiency, life and maintenance (see later section on quality).

Radiation - The process of transfer of energy through space, and often the term is used to denote the energy. Visible and infrared energy are transferred by radiation.

Rating - The rating of a lamp concerns the principal design parameters for life, lumens, watts, etc.

THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Refraction - The bending of light rays when passing from a medium of one density to another of a different density. Rays of different wavelength are refracted differently.

Regular Lamps - Regular lamps are those designed for the normal electrical supply voltages, are in great demand and are regularly available. Special lamps are sometimes manufactured to order only.

Ribbon Filament - A ribbon filament lamp is one in which the filament is made in the shape of a flat ribbon versus the normal filament of round wire. Quite often these are made for standards.

Secondary Standard - Secondary standard lamps are made by calibrating against the primary standard lamp. Sometimes they are called "working" standard lamps.

Spectrophotometer - A device for measuring the relative amount of energy at different wavelengths.

Symmetric Distribution of Light - Symmetric distribution is the uniform distribution of light about the vertical axis of a lamp.

Test Lamp - Test lamps are those lamps which are being measured for their characteristics.

Translucent - Translucence is the ability of a medium to transmit light; however, it also diffuses the light to break up images, e.g. opal and frosted glass.

Transmission - Transmission of light is the passage of light through a medium. The ratio of transmitted light to incident light is the Transmission Factor.

Transparent - Transparency is the characteristic of a medium which transmits light without diffusing it. Object can be viewed without distortion.

Ultra-violet Radiation - Ultra-violet radiations are those which are of shorter wavelength than the shortest in the visible range.

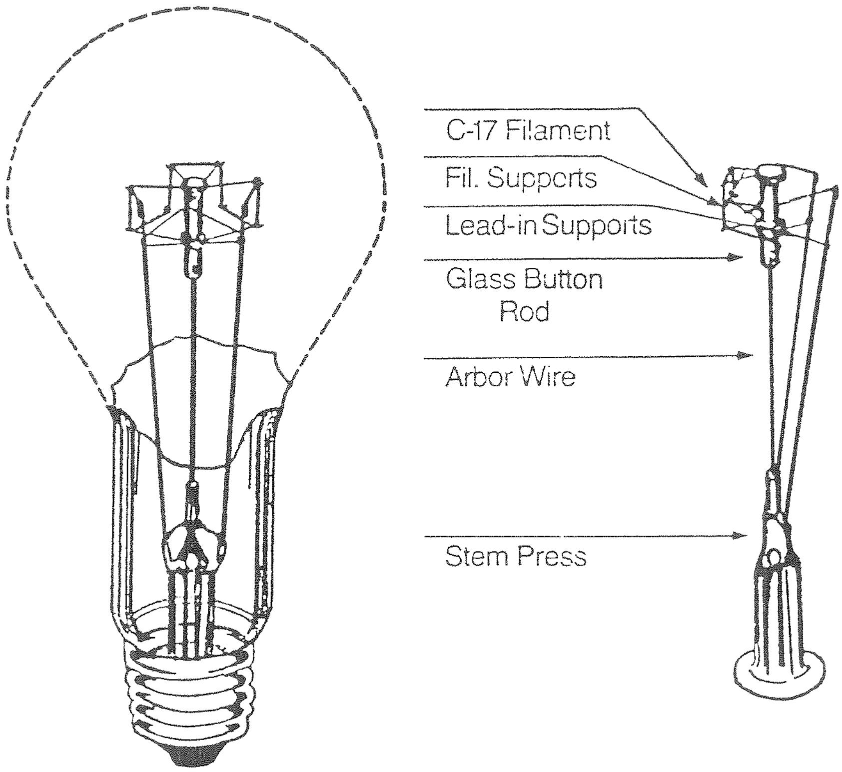
THE LANGUAGE -- SOME TERMS DEFINED - (CONT.)

Vacuum Lamp - A vacuum lamp is an incandescent lamp having its filament operating in an absence of any gas or a very low partial pressure of inert gas (trace). Generally, these are known as type B lamps and usually only small size filaments are used.

Visibility - The ability to see or be seen under conditions of distance, light, and atmosphere prevailing at the time.

Wavelength - The distance measured of a complete wave, assuming the theory of undulation. Wavelength varies inversely as the frequency. Wavelength is measured in Nanometers, Angstrom Units and Microns.

Figure 9 - Typical Rough Service Lamp

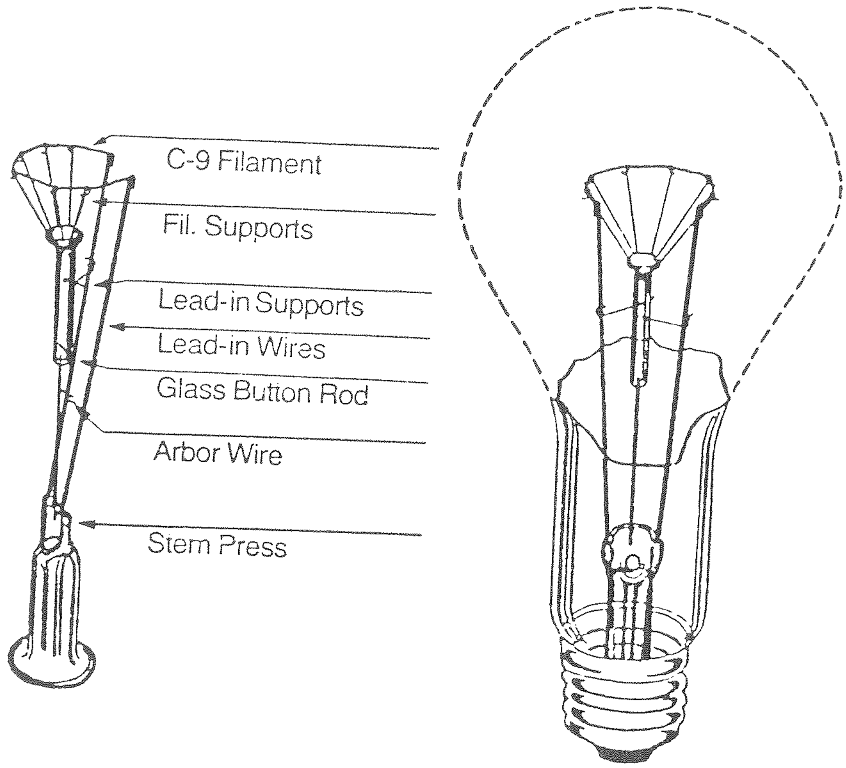


Lead-in Wires - The lead-in wires join the ends of the filament to the contacts on the base for connection with the electrical source. Leads are made in sections of selected materials; the section passing through the press forms an hermetical seal.

Stem Press - The stem press is the point in the lamp where the hermetic seal between the glass and the lead-in wires is accomplished.

Exhaust Tube - The exhaust tube is of glass through which the air is removed and in the case of other than vacuum lamps, special gas is added before this tube is sealed.

Figure 10 - Typical Vibration Service Lamp



Filament Supports - Filament supports are usually molybdenum or tungsten wires, one end embedded in a glass button and the opposite end in contact with the filament to hold or support it.

Button - The button is normally the flattened and shaped end of a glass tube or cane. It holds the filament supports in position.

Heat Reflector - The heat reflector, often made of aluminum, protects the base from becoming too hot.

Fuse - The fuse is a section of a lead wire designed to melt and open the circuit if excessive current is established in the lamp, e.g., arcing condition.

15.2 LIGHTING UNITS

Base - The base is the device attached to the bulb and designed to connect the lamp to a given type of electrical lamp socket.

Lamp Atmosphere - The lamp atmosphere may be either a high vacuum or a special gas. Most low wattage lamps are vacuum types. Large wattage lamps are gas filled.

Lamp Classification - There are three major groups: large lamps, miniature lamps and photographic lamps However, there is no distinct division between groups. The large lamp groups includes those generally of large wattage and bulb size.

15.3 RULES OF THUMB

15.3.1 LAMP PERFORMANCE

+ 1% Lpw = -7% life

+ 1% volts = -14% life

+ 1% current = -27% life

+ 1% volts = +3.4% lumens

+ 1% current = +6.4% lumens

15.3.2 FILAMENT DESIGN

+ 1% Wire Weight = + 2% life at constant Lpw

Effect of Filament Wire Size and Mandrel Size Tolerances

+ 1% Wire Wgt. = 0.80% Watts, + 0.80% Lpw
+ 1% Wire Length = -0.55% Watts, -1.80% Lpw
+ 3% Wire Wgt. of Moly Mandrel = +1.5% change in filament wire length

Effect of Coil Winding Parometer Tolerance

+ 1% T.P.I. = -0.11% Watts, + 0.48% L.P.W.
+ 1% L.P.W. = -7% life

15.3.3 EFFECT OF FILAMENT MOUNTING VARIATIONS

If an error made in mounting the coil is such that the lighted filament length is shortened, the following relationships occur:

1% L.T.S. (Lead Tip Spacing) = -(10 - 12%) Life
+ 0.5% Current
+ 0.5% Wattage
+(1.5 - 1.75%) L.P.W.
+(2 - 2½%) Lumens

15.3.4 WIRE VARIATIONS -- WIRE WEIGHT AND WIRE LENGTH

+ 1% Wire Wgt. = + 0.80% Watts, + 0.80% Lpw
+ 1% Wire Length = - 0.55% Watts, - 1.80% Lpw

By simultaneous equations, the above data can be converted to equations for constant watts or constant lpw.

Constant Watts

Vacuum Lamps or Gas-Filled Lamps
+ 1% lpw = -0.55% Wire Weight, -0.80% Wire Length

Constant Lpw

Vacuum or Gas-Filled Lamps
+ 1% Watts = +1.80% Wire Weight, + 0.80% Wire Length

15.3.5 LAMP LIFE AS A FUNCTION OF CURRENT

CC-8 (With Center Support) Gas-Filled Lamps
750 Hour $Lpw = 18\ I^{.25}$

CC-9 or CC-6 Gas-Filled Lamps
1000 Hour $Lpw = 16.498\ I^{.254}$

C-9 Gas-Filled Lamps
1000 Hour $Lpw = 15.54\ I^{.32}$

C-9 Vacuum Lamps
1000 Hour $Lpw = 11.36\ I^{.157}$

15.3.5 LAMP LIFE AS A FUNCTION OF CURRENT - (CONT.)

The Lpw values calculated by the aforementioned formulas are good to about + 3% of actual and can be used to design filaments for a particular life where Lpw is not specified. These formulas are for A-line or GLS types only.

For lives other than those indicated, the lpw can be calculated:

$$\left[\frac{\text{Old life}}{\text{New life}}\right]^{\frac{1}{7}} = \left[\frac{\text{New lpw}}{\text{Old lpw}}\right]$$

15.3.6 CLAMPING

Single Coil with legs -- Clamp thickness should be twice lead flat thickness minus 1 mil (25 microns)

Continuous Single Coils for low wattage lamps -- Clamp thickness should be twice lead flat thickness minus 1 mil (25 microns)

Continuous Single Coils and Coiled Coils with low mandrel to wire ratios. -- Clamp thickness should be twice lead flat thickness plus 70% of coil diameter.

General -- With a pencil, pull the center section of the filament until the filament breaks. The filament should stretch to three times its normal length before it breaks. The filament should not pull out of the clamp.

15.3.7 APPROXIMATE CALCULATIONS

15.3.7.1 TEMPERATURE AND LPW

Convert Lumens per watt to Color Temperature

$$Lpw^{.2326} \times 1479 = \text{Color Temperature } {}^{o}K$$

Convert Lumens per watt to True Temperature

$$Lpw^{.21} \times 1486 = \text{True Temperature } {}^{o}K$$

(Lpw 11 to 24)

$$Lpw^{.15} \times 1703 = \text{True Temperature } {}^{o}K$$

(Lpw 2-11)

Convert Brightness ^{o}C to Lumens per watt

$$\text{Brightness } {}^{o}C^{4.6688} \times 4.5624^{-15} = lpw$$

Convert Brightness ^{o}C to True Temperature ^{o}K

$$\text{Brightness } {}^{o}C \times 1.2528 = \text{True Temperature } {}^{o}K$$

15.3.8 RULES OF GOOD GLASS PRACTICE

In general, the major points to remember about good glass practice in incandescent lamp-making can be listed as follows:

1. Glass is an insulator so heat cannot move quickly and uniformly through it.
2. Glass breaks only when in tension.
3. Heating and cooling must be carried out as slowly as possible; in the annealing range to reduce the permanent stresses that will cause delayed cracks to occur, and below the strain point, to minimize the temporary stresses from exceeding its tensile strength limit,

15.3.8 RULES OF GOOD GLASS PRACTICE - (CONT.)

3. causing immediate cracks to occur; during pre-heating or final cooling.

4. Sharp angles in its shape will reduce its strength considerably.

5. Glass should be heated to 20 - 50°C below strain point for degassing.

15.3.9 BASING CEMENT FRESHNESS

There is a "rule of thumb" which can be used to determine the freshness of basing cement. If you can take some of the cement out of the base and ball it up in your fingers, the cement is probably soft enough to use. If it falls apart in your fingers it is obviously old.

Base tests are made daily to determine how the base stays on the lamp. The lamp is placed in a base tester by first screwing it into the holder. Rubber cups are then adjusted so they grip the maximum diameter of the lamp. A torque is placed on the bulb. When the bulb loosens from the base, a pointer will indicate the failure in inch-pounds - a good score is around 100.

A Boiling Water Test is also made. The lamps are placed in boiling water for a few minutes then partially dried. A torque test is made and the reading recorded. This test is made to simulate the shelf life of the base on the lamp during warehousing.

15.3.10 Zr GETTER

Zr getter or Zr Al getter should turn dark gray to black during lamp operation. No color change indicates getter is not hot enough and is not functioning properly.

15.4 INCANDESCENT LAMP "TRIVIA"

A review of old papers and books on incandescent lamps indicates the meaning of some terms have changed and some terms eliminated.

1. Everyone knows a "B" lamp is a vacuum lamp and a "C" lamp is gas-filled. What is an "A" lamp?

   Answer: The first commercial vacuum lamp with a tungsten filament was called a Mazda A lamp. The filament was made of pressed or squirted tungsten. The following list is the nomenclature of early lamps.

   Mazda A - Vacuum, clear bulb, pressed wire.
   Mazda B - Vacuum, clear bulb, drawn wire.
   Mazda C - Gas-filled, clear bulb, drawn wire.

2. When referring to bulbs, "G" stands for globular, "F" stands for flametint, "T" for tubular, "PS" for pear-shaped, "S" for sign-lighting, etc. The most popular bulb is the "A" bulb. What does "A" stand for?

   Answer: Since 1925 lamp bulbs have been frosted on the inside. The shape of the frosted bulb corresponds to the average of the S, G, T and PS shapes and hence was designated as the "A" bulb. The term A-line lamps refers to gas-filled, frosted inside, drawn wire lamps with the "A" shape bulb. The "A" stands for average.

15.4 INCANDESCENT LAMP "TRIVIA" - (CONT.)

3. Standard lamp voltage in this country is now 120 volts. It used to be 110 volts. How was 110 volts arrived at?

   Answer: The Edison lamp was a carbonized bamboo filament in a vacuum lamp. Edison felt that if much more than 110 volts were applied to such a lamp, the filament would shatter. On the other hand if the voltage were much below 110 volts, the current would be high and hence a great amount of copper required. These considerations led Edison to prefer 110 volts.

4. Present lamps are rated in watts and lumens per watt. How were early lamps rated?

   Answer: The lamps were rated in horsepower and usually eight lamps to one horsepower. 1 hp = 746 watts. Since there was no central power plant and distribution, each lighting application required a dynamo. The horsepower of the dynamo was a function of the number of lamps on the circuit.

5. Flashing is a term used to describe the initial light up schedule of an incandescent lamp. Flashing is done to prevent arcs and to set coil structure for prevention of coil sag. What was the original purpose of flashing?

   Answer: Messrs. Sawyer and Mann are responsible for "flashing" the filament. They attempted to burn a carbon filament in a hydrocarbon gas so that the filament would not become oxidized. They use illuminating gas and found that a deposit was formed on the weak spots of the carbon filament when it was heated. This served to make the filament a uniform thickness, improved the life, and the process of "flashing" was generally adopted.

15.4 INCANDESCENT LAMP "TRIVIA" - (CONT.)

6. There has been a great deal of work done to prevent hot spots which cause coil failure. How did early lamp engineers cope with this problem?

   Answer: "The filament is coiled on a large mandrel and if the filament becomes weaker at a given spot the "spiral" will stretch, thus giving a greater access of the convected gas to the weak spot to cool the weak spot. In this way the resistance is reduced, with a consequent reduction in power loss and deterioration." NOTE: No mention of reduction in mutual radiation due to pitch change. D.D.

7. A sunlap is presently a self ballasted Mercury arc lamp. What was the 400 watt S-1 sunlamp?

   Answer: The 400 watt S-1 Incandescent sunlamp contains a drop of mercury. The mercury vaporizes, and the light produced comes from a mercury arc as well as from the tungsten filament, giving nearly white light with considerable ultraviolet.

8. What was original term for night lights?

   Answer: Moonlights (3 watt) were developed to bring "moonlight" indoors.

9. G. E. adopted the Mazda trademark in 1909. Where did the word Mazda come from?

   Answer: The name Mazda was taken from the Persian God of Light, Ahura Mazda. It was applied to lamps constructed on the basis of latest technical developments.

15.4 INCANDESCENT LAMP "TRIVIA" - (CONT.)

10. The efficiency of present lamps is measured in LPW, MSCP, candles per watt etc. How were early vacuum lamps (straight wire filaments) measured?

    Answer: Horizontal Candlepower. "Since the horizontal candlepower of a Mazda "B" lamp as now made is numerically just about equal to the number of watts consumed and as 4π times the spherical reduction factor (.7854) is approximately 10, it follows that the Mazda "B" lamp generates approximately 10 lumens per watt." NOTE: Until coiled filaments came along lamps were rated on horizontal candlepower not mean spherical candlepower or lumens. D.D.

11. Present automotive headlighting specifications limit candlepower to 75,000. Proposed regulation will allow 150,000. Europe allows 300,000 cp. What was SAE - IES limit in 1928?

    Answer: Headlights 36" above road.
    1° up 2400 cp maximum 800 minimum.
    0° 6000 cp maximum 1800 minimum.
    1° down 7200 cp minimum.
    1° down 1° right 25,000 cp minimum.
    1½ down 3° left and right 10,000 cp minimum.

12. A present stem has a part called a flare. What was the old name of the flare.

    Answer: The large glass tube is called the stem tube and has a "flange" rolled on one end. Such lamps are called flange seal lamps.

15.4 INCANDESCENT LAMP "TRIVIA" - (CONT.)

13. Present filaments are wound on steel or moly mandrels. What other material was used in early lamps?

Answer: Tungsten filament wire is coiled on brass or iron mandrels on automatic coiling machines running at 5-10,000 rpm.

14. What is definition of a miniature lamp?

Answer: Miniature lamps are designed to operate below 50 volts. Miniature lamps are usually small but a 1000 watt sealed beam lamp is considered a miniature lamp if voltage is below 50 volts.

15. Getter is a term applied to materials which remove H_2 and O_2 from vacuum and gas filled lamps to prevent water cycle. What were early getters used for?

Answer: In addition to improving vacuum, materials were used (borium chlorate) to produce oxygen which would oxidize tungsten on the bulb wall and make it transparent and thereby improve maintenance of vacuum lamps.

16. Halogen cycles presently apply to hard glass and quartz lamps. Is there a vacuum halogen lamp?

Answer: The observation on the dissociation of Cl and O_2 at the surface of an incandescent filament account for the operation of the so called "regenerative getters" used formerly in the commercial production of vacuum lamps. Materials such as tungsten oxychloride and potassium thallium chloride were used. Atomic Cl would combine with tungsten on the wall and thus maintain a clear glass surface for a much longer time than in absence of these getters.

15.4 INCANDESCENT LAMP "TRIVIA" - (CONT.)

17. A single coil or coiled coil is made from tungsten filament wire. The coil or filament is the light source. What was the original term for the coil or filament?

Answer: The light source was called a burner in the same sense that the gas mantle light source was called a burner.

18. Present lamps are called tipless because the tip is inside the base. When the tip was at dome of the bulb what was it called?

Answer: The remaining projection was called the pip and when the present stem was developed, the lamp became pipless. NOTE: There is some confliction on this one. Pip may have been the British term for tip. D.D.

19. Early gas-filled lamps had a special name which has long disappeared. What was it?

Answer: The early gas-filled lamps were called Half Watt lamps. The efficiency was about one candle per half watt.

20. The useful life of present incandescent lamps is their full life right up to failure. What did the term "useful life" mean about 1900?

Answer: Carbon filament lamps deteriorated during life due to carbon evaporating and condensing on the bulb. The useful life of a carbon lamp (Mazda A or B) was reached when light output reached 80% of original light output.

15.4 INCANDESCENT LAMP "TRIVIA" - (CONT.)

21. A lamp tester today would probably be a device to check lamp characteristics to see if lamp was within specifications. What was a lamp tester 70 years ago?

    Answer: The wattage of a lamp and its candlepower was unknown until the lamp was completed. The lamp tester made various measurements and then decided what the wattage was and segregated lamps and sold them accordingly. The early carbon filaments were carved by hand and varied over a wide range.

22. The common lamp voltage in U.S. is 120 volts. In Europe, the common lamp voltage is 240 volts. Why is Europe different than U.S.A.?

    Answer: Originally, European lamps were 110 volts. When mains were installed from power stations, they underestimated the number of lights people would use. A decision was made to increase voltage rather than replace mains with larger wire. This change over occurred before W.W.I.

23. Hundreds of millions of homes all over the world have electric lights. Where and when was the first building illuminated by electric incandescent lights?

    Answer: Moses Farmer used 42 lamps to light up rooms in his home at 11 Pearl Street, Salem, Mass. on July 15, 1859. He used 42 circuits, one lamp on each circuit. The filaments were platinum. Thomas Edison would have been in sixth grade at the time.

15.5 LIST OF TRAINING PACKAGES

(In Numerical Order)

for

Equipment Development Training Program

1. Number Identification System
2. Bearings
3. Belt Drives
4. Chain Drives
5. Gear Drives
6. Cams and Followers (General)
7. Keys and Fasteners
8. Levers and Linkages
9. Springs
10. Hand Tools
11. Trouble Shooting
12. Lubrication and Lubricants
13. Air Controls
14. Solenoids
15. Vibratory Feeders
16. Simple Electric Circuitry
17. Lead Wire Feed and Form (FC-1, AG-1)
18. Part 1 - Gravity Type Lead Wire Feeders
19. Part 2 - Positive Type Lead Wire Feeders
20. Part 3 - Hairpin Type Lead Wire Feeders
21. Filament Mounting Devices (AG-1, FC-1)
22. Resistance Welding
23. Side Wire Welding
24. Introduction to Quality
25. Gettering

15.5

LIST OF TRAINING PACKAGES

(In Numerical Order)

for

Equipment Development Training Program

26. Side Wire Inserters - Introduction
27. Side Wire Inserter - Old Sylvania Type
28. Side Wire Inserter - New Sylvania Type
29. Side Wire Inserter - Miniature Lamp Type
30. lare Making
31. Lead Wire Loader & Transfer Device - Hi-Speed Type
32. Flashing
33. Cam Design (Perameters)
34. Cam Design (Curves)
35. Stem Making
36. Stem Head Alignment
37. Stem Making Process (400' Movie)
38. Sealing & Tipping (Incandescent Lamps)
39. Exhaust Systems
40. Computerized Cam Design

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15.6 ABBREVIATIONS

BC or B22	Bayonet
SBC or B15	Small Bayonet
GES or E40	Goliath Edison Screw
ES or E27	Edison Screw
SES or E14	Small Edison Screw
MES or E10	Miniature Edison Screw
NS	Non Sag
TH	Thoriated
B	Vacuum Lamp
C	Gas-Filled Lamp
SC	Single Coil
CC	Coded Coil
A	Standard Bulb Shape
PS	Pear Shaped
Model 501	GE Stem and Mount Machine
Model 169	GE Base Filling Machine
Model 174	GE Sealex
Model E-3	GE Vertical Flare Machine