

COMMERCIAL NEON TUBES

BY

JOSEPH FREDERICK FOSSICK

AND

OLIVER DEWITT FLEMING

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INTRODUCTION.

Owing to the increasing use of neon signs for commercial advertising, and the small amount of scattered data that is available upon the characteristics of these tubes, we have endeavored to collect this data and have supplemented it by tests conducted by ourselves.

Most of the published data on neon tubes deals with the installation as a whole; taking measurements from the low tension side of the step-up transformer. We have also made measurements on the installation as a whole, but have included a test of the transformer from which the actual currents and voltages on the tube can be obtained through calculations. We have also made tests on the tube itself for current values.

GENERAL SURVEY OF THE FIELD.

The neon lighting industry has reached world wide proportions in the last few years. In the United States the neon business alone totaled \$25,000,000. last year. The use of the neon signs in advertising lighting is increasing in the larger cities of Europe, Australia, New Zealand, China, and Japan.

The increasing popularity of neon tubes is due to their several outstanding advantages for electric display lighting. The colored light in contrast with the sunlight shows to advantage in the daytime. The signs have an evenly distributed light which makes letters traced with them easily read. Neon is a cold light, thereby the loss due to heat is very small; this makes the neon sign very economical in operation.

Neon lights have played a vital part in the development and perfection of such apparatus as telephoto and television, owing to the fact that neon may be flashed with almost instantaneous precision. Because of the fact that neon tubes will glow when placed in an electrostatic field they have been used for several years to provide visual indication of energized high voltage conductors. However, this indication is merely used as a secondary means of determining whether a conductor is energized or not. The tubes are also used as pilot lights due to their small current capacity.

The neon tube is rapidly becoming of prime importance in the aerial beacon field due to its low maintenance cost, low operating cost, and the ability of the red glow to penetrate

fog and smoke. The thirty-three millimeter tubing with a current consumption of approximately 200 milliamps when operating is visible for about 25 miles.

Until lately, the majority of power companies looked unfavorably upon large installation due to the low power-factor, but since the neon sign is only a fraction of the lighting installation, its low power factor has no appreciable effect upon the power factor of the total load. Because of the low operating cost, and the greater possibility of design and color, neon has interested many businesses that previously did not use electric advertising; architects are cooperating in the proper selection of neon displays and have gone so far as to include them in their original plans. This greater use of electric advertising is building rather than diminishing the sign load.

DESCRIPTION OF METHOD AND APPARATUS USED

Due to the fact that no high voltage instruments, that would operate on the small amount of current available on the high tension side of the transformer, could be had, all measurements were made on the primary side of the transformer, except occillograph reading of the current, which were made on the high tension side.

This method of attack involved a complete test of the transformer used, and calculations in order to convert primary readings to secondary readings.

At first, an attempt was made to use a ball Voltmeter, but owing to the small current taken by the tubes this was found to be very unsatisfactory.

Because of the fact that current taken by the occillograph was equal to, or more than, the capacity of the transformer secondary, it could not be used to secure voltage readings.

There were several sources of error. The instruments used were accurate to within one percent of full scale deflection. Also an error of approximately one percent may be due to handling of small values in calculations when changing primary readings to secondary readings.

The precautions taken to avoid these errors were: The selection of instruments to give as near as possible full scale deflection and measurement of resistance of leads when they made an appreciable amount of difference, as in finding the resistance of the primary of the transformer.

The apparatus used was: A standard 250 V. A. neon sign transformer, ratio of one to one hundred. The tubes were of

various sizes, length, colors and gas density corresponding to commercial practice. The measuring instruments used were: G. E. Three element occillograph, voltmeter, ammeter, and wattmeter. A pencil mark rheostat of four hundred and thirty-two thousand ohms was used in series with the tube and occillograph element in one of the current measurements on high tension side.

CONSTRUCTION PECULIARITIES

As a rule, the usual house current, 110 Volts, is brought to the sign outlet. Inside the sign the current is passed through a step-up transformer to secure the necessary voltage. Proper electrodes and pure neon gas must be used in the tubes in order to get efficient light. Otherwise a sputtering and using up of neon molecules, and thus a dimming of the light will occur. Although neon tubes will glow in an electrostatic field, the most uniform and efficient brilliance is obtained by means of high-voltage alternating current.

Lead glass is used for the tubes because of its durability and flexibility under the application of heat. The tubes are bought in four foot standard lengths of 15 and 11 Millimeters in diameter. These lengths are welded end to end when greater length is required, and are bent in the proper shape by heating. Copper shell electrodes are sealed on the ends of the tubes.

The gas is allowed to enter the tube under the desired pressure (15 Millimeters of mercury is the usual value) and later sealed. All the air must, of course, be exhausted before the gas enters. To purify the tubes a very high voltage is passed through the tube until it heats the glass wall to slightly less than the melting point, and the electrodes are heated to a cherry red color. After the tubes are cooled they are subjected to a high vacuum and the pure neon admitted.

Factors Determining Life.

When electric current passes from the electrodes to the neon gas a sputtering takes place, this means that particles

of the electrode are loosened and deposited on the walls of the tube. The sputtering is overcome by the use of sufficiently large electrodes. The length of the life of neon tubes depends a great deal upon the size of electrodes. By using electrodes of a minimum ratio of 1.5 square decimeters for each ampere of current, a burning life of more than 25,000 hours can be obtained. Smaller electrodes have been used, but only a life of from 1,000 to 3,000 hours was obtained. The electrode must be built to fit the case; higher pressure and denser gas, length of tube, and brilliancy required are all factors entering in.

The efficiency of the neon light may be judged by the fact that it consumes only about one-fifth to one-tenth of that required for a lamp display of equal power. This saving of energy tends to make the user burn neon lights during the daytime as well as at night. In some parts of Germany the neon lights are allowed to remain burning 24 hours a day, because the wear and tear, and the extra energy consumed, amounts to less than the cost of labor to turn them off and on.

GENERAL THEORY

When a high voltage current is passed through neon gas, the gas is ionized, giving off a reddish glow. Owing to the fact that almost all the radiation is in the visible part of the spectrum, this tube is known as the cold cathode tube.

High voltage, ranging from 700 volts for a one foot tube to about 3,000 volts for a twelve foot tube, is required to start an appreciable amount of current through the tube. The amount of current required for a sufficient illumination is about 20 milliamperes. Because of the small current and high voltage the values for current and voltage could not be obtained satisfactorily, therefore, readings were taken on the low voltage side of the transformer. To obtain the secondary values of current and voltage it is necessary to find the characteristics of the transformer and calculate these values.

An Occillograph can be used to get the secondary current, but due to the low current capacity of the transformer, the voltage cannot be obtained satisfactorily, for the current is insufficient to operate the occillograph vibrator.

The tubes used in this test were as follows:

Length :	Diameter :	Pressure :	Gas :	Color
Ft. :	Millimeters :	Millimeters of Mercury. :	Kind :	
5 :	15 :	15 :	Neon :	Red
1 :	11 :	10 :	Neon :	Red
1 :	11 :	5 :	Neon :	Red
1 :	15 :	10 :	Mercury :	Green
1 :	15 :	15 :	Neon :	Blue
:	:	:	Mercury :	
:	:	:	Neon :	

It will be noticed in the table that pure neon gives a red light; a mixture of mercury and neon gives a blue glow; and a green light is secured by painting the outside of the tube yellow and filling it with mercury and neon. These colors are the only ones that are used for commercial purposes.

THE TRANSFORMER

The latest development in transformers for the neon sign is a transformer with very marked characteristics. The R l drop of these transformers is very small as compared to the X l drop. This causes the current regulation to be low relative to the voltage.

The importance of the low current regulation is to insure a uniform brilliancy of illumination with various lengths of tubing. The special type of transformer has good current load characteristics, and hence its use assures uniform brilliancy, long life of tubing, and continued cool operation under all conditions.

Many factors enter into cool operation. The silicon steel cores are scientifically shaped, proportioned and designed. Oversized wires are used in both primary and secondary windings, these coils being properly located in the transformer to insure best heat radiation.

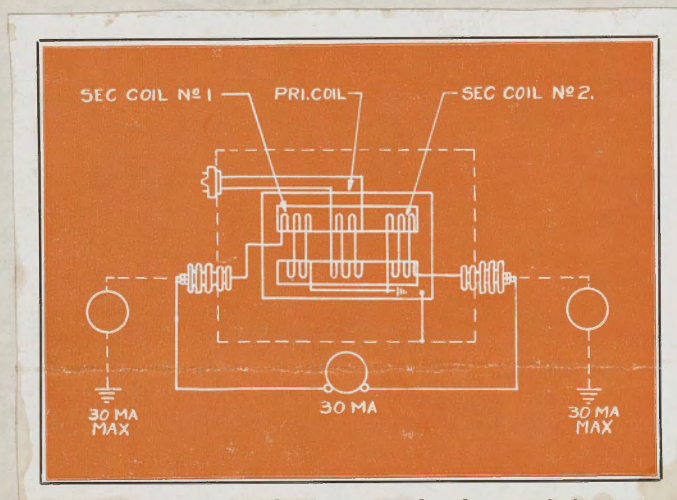
Induction coils with silicon steel cores are used for limiting the current flow, and these are of such design as to give maximum tube footage and cool operation. The coils are driven into place and locked after assembly. The distributions of these coils is such that a balanced and limited secondary current is permitted in either secondary coil when the secondary of the transformer is shorted or either high tension terminal is grounded, which does not subject the primary or secondary coils to overload. Under any of the above conditions the current in the secondary circuit does not exceed that of short circuit.

The secondary coils are lay-built windings of large electrical conductors of enameled copper wire, and are thoroughly impregnated under pressure with an insulating compound. Heavy die formed mica insulators surround the secondary coils which afford perfect insulation of these windings.

The primary winding is wound in layer form of a large sized copper conductor and treated against moisture by varnish. The coil is narrow which helps much in radiation of the developed heat.

The transformer is grounded at the midpoint which insures the maximum voltage stresses definitely limited to one-half of those which could exist if an insulated transformer were used. It also assists in limiting the maximum secondary current which can flow under any conditions of normal or abnormal operation to a value which cannot be injurious to the transformer.

The following sketch illustrates the characteristics of a midpoint grounded, balanced design transformer having a normal short circuited secondary current of 30 M. A.:



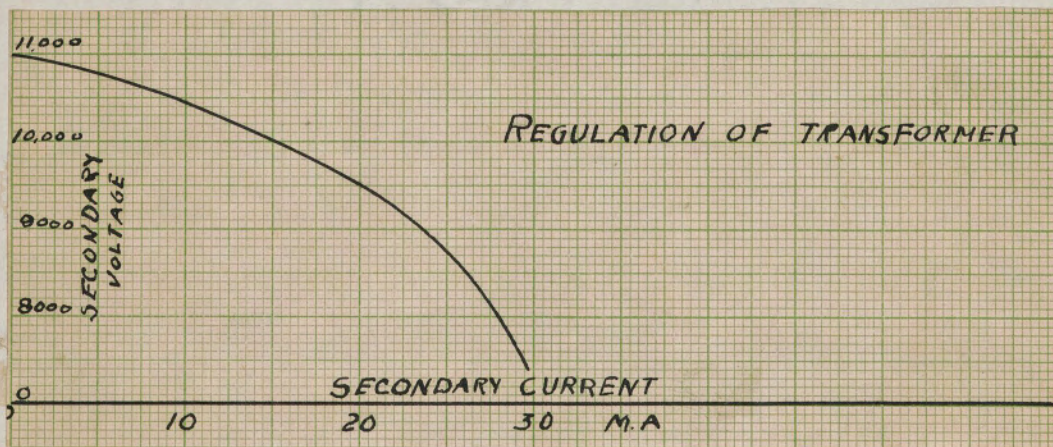
Regulation

at 22% Power Factor = 99.9%

at 100% Power Factor = 50.7%

Secondary current and Secondary voltage -

I Amps	E Volts
.001	10964
.005	10800
.010	10435
.015	10005
.017	9824
.020	9527

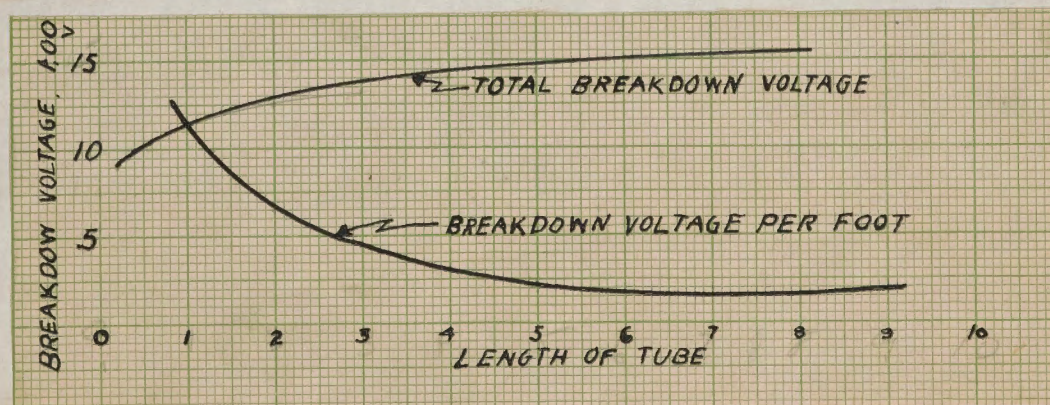
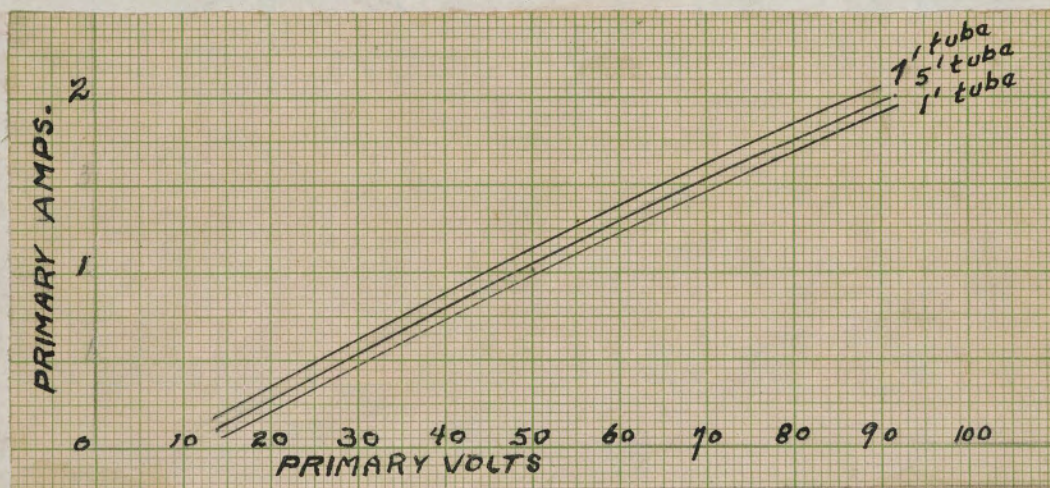


OBSERVATIONS AND CONCLUSIONS

Upon test it was found that the tubes would not operate successfully in parallel. One section of the parallel circuit would glow while the other would remain dark. Upon starting the same leg of the parallel circuit would not always glow.

The break down voltage was taken as that voltage that caused a sufficient current to flow to give an appreciable glow.

The breakdown voltage of two tubes in series is not the sum of their breakdown voltages, but is less. It can be seen from the figure below that the breakdown voltage per foot for several tubes in series falls off rapidly from 1 foot to 5 feet of tubing running almost horizontal from there out.



It can also be seen from the figure that the length of the tube measures the voltage required for breakdown. Also the operating voltage increases with the length of the tube.

Owing to the characteristics of the transformer the current remains practically constant under operating conditions.

A peculiar characteristic of the tube is shown by the oscillograph pictures of the current through the tubes. This wave form is a sine wave. This indicates that the tube under operation voltage breaks down at zero voltage.

These pictures were made with the oscillograph element in series with the tubes without and with a resistance. No difference was noticed for these different conditions.

Upon measurement these pictures showed the current constant for various lengths of tubing.

The power factor of the tubes was greatest at breakdown voltage, decreasing with increase of voltage, varying through a wide range. This variation may be seen in the tables.

The greater the length of the tube the less the watts per lineal foot. This is one of the chief advantages of long lengths of tubes in series.

Frequency variation from 50 to 80 cycles had no apparent effect upon the operation of the tube. It has been found, however, that for frequencies above three thousand (3000) kilocycles, there will be dark and light spots in the tube.

The test data of the Transformer follows:

Open circuit test - secondary open

Primary Volts	=	110
Frequency	=	60 cycles
Primary Amperes	=	0.48
Input V. A.	=	53
Primary Watts	=	12
Power Factor	=	22.6%

Short circuit test - secondary short circuited

Primary Volts	=	110
Frequency	=	60 cycles
Primary Amperes	=	2.8
Input V. A.	=	308
Primary Watts	=	36
Secondary M. A.	=	24.5
Power Factor	=	11.7

Resistance by Wheatstone Bridge

Primary Resistance	=	1.66 ohms
Secondary Resistance	=	19,100 ohms
Equivalent Resistance	=	4.61 (reduced to primary side.)

A P P E N D I X

Operating Characteristics, Including Transformer and Tubes.

No Electrodes	Pressure Gas M.M.	M. M. Tubing	Length Of Tube	Watts	A _p	E _p	V.A.	P _f	W Per Foot
2	15 Neon	15	5	15.25	2	91.5	183	8.4	3.05
2	15 Neon	15	1	10.25	2	91.	182	5.6	10.25
2	10 Neon	11	1	10.72	2	91.	182	5.9	10.75
2	5 Neon	11	1	10.1	2	91.2	182.4	5.5	10.10
2	10 Neon 5 Hg	15	1	10.1	2	91.1	182.2	5.6	10.10
2	10 Neon 5 Hg	15	1	10.05	2	91.0	182	5.5	10.05
4	15 Neon	15	2	12.5	2	91.6	183.2	6.8	6.25
6	15 Neon	15	7	16.4	2	93.0	186	8.8	2.34
4	15 Neon	15	6	17.25	2	93.0	186	9.3	2.88

5 Neon Tube 15 M. M. 15 M.M. of Hg. Pressure

Operation from breakdown voltages up.

Volts	Current	Watts	Power Factor
14.3	Could not read		
11.6	Could not read		
15	.05	52	66.7
26	.49	6	47.1
50	1.0	13	26.0
58	1.2	17	24.4
62	1.28	18.75	23.6
70	1.48	22.7	21.9
76	1.6	25.5	22.0
82	1.75	30	20.9
88	1.9	34	20.3
92	2.02	38.5	20.7
110	2.75	55	18.2

1 Neon Tube 15 M. M.

Voltage	Current	Watts	Power Factor
11.7	0.16	Breakdown voltage	
5.8	0.17	Sustaining voltage	
15	0.37	2.5	44.4
30	0.63	3.75	19.8
40	0.845	6	17.8
50	1.1	9	16.4
60	1.3	12	15.4
70	1.55	17	15.8
80	1.75	21.5	15.4
90	2	27	15.0

2 - 1 Tubes in series

Voltage	Current	Watts	P.F.
13.5	0.1	Breakdown voltage	
8	0.1	Sustaining voltage	
15	0.35	3.25	62.0
40	0.84	7.6	22.6
50	1.03	11	17.9
60	1.33	15.35	19.2
70	1.53	20.5	18.95
80	1.75	24.5	17.5
90	2.0	31.5	17.5

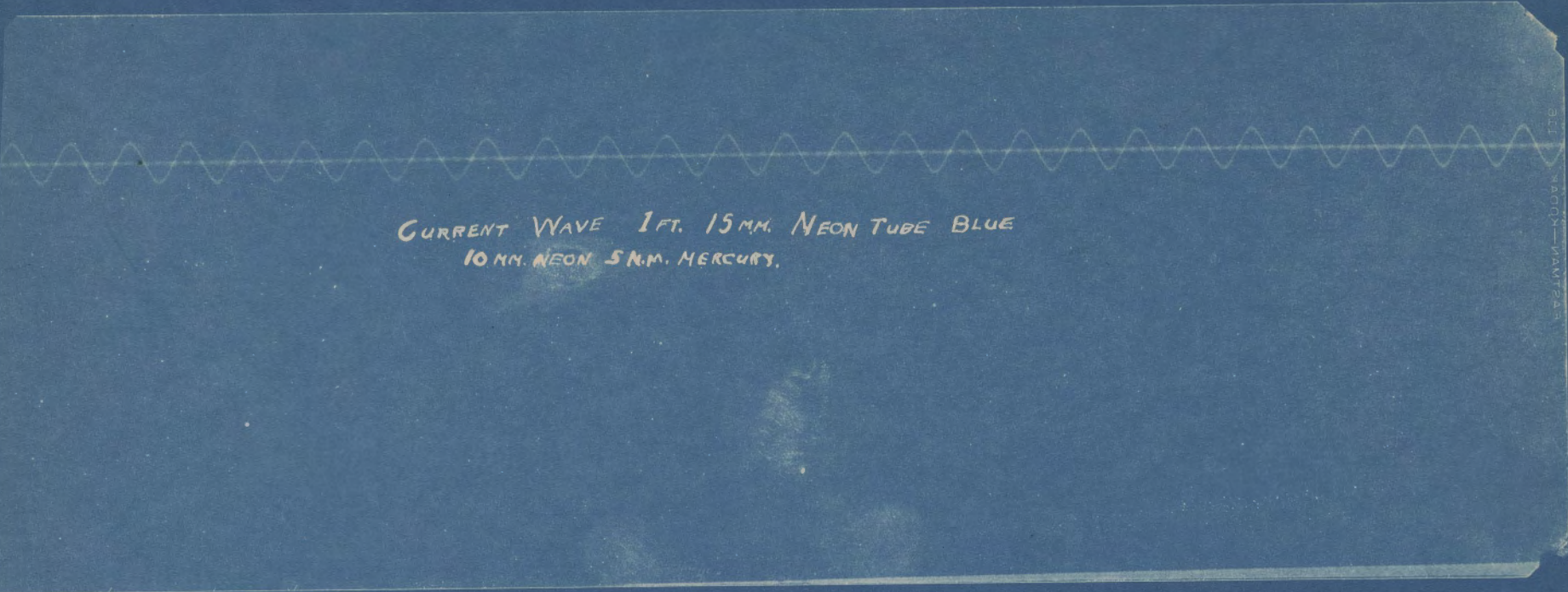
5 and 1 Tube in series

Voltage	Current	Watts	P.F.
14	0.1	Breakdown voltage	
20	.42	2.55	30.4
40	.80	11	34.4
50	1.01	15	29.7
60	1.26	20.5	27.2
70	1.48	26.0	25.3
80	1.72	32.5	23.6
90	1.97	40.	22.6
91.5	2	41	22.6

5 and 2 - 1 Tubes in series

Voltage	Current	Watts	P.F.
14.5	0.1	Breakdown voltage	
20	0.4	5.	62.5
30	0.52	7.5	45.2
40	0.77	12	39.0
50	1.2	17	28.4
60	1.28	24	31.3
70	1.48	28.5	27.6
80	1.71	35	25.3
92	2	45	24.4

19.



CURRENT WAVE 1 FT. 15 MM. NEON TUBE BLUE
10 MM. NEON 5 M.M. MERCURY.

311 NADON—NANTAS

CURRENT WAVE NEON TUBE 1 FT. RED
15 M.M. TUBE 15 M.M. NEON



CURRENT WAVE NEON TUBE RED 15 M.M. TUBE.
10 M.M. NEON GAS. I



CURRENT WAVE 5 FT. NEON TUBE
STANDARD RED. 15 M.M. TUBING.

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APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statement made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name Chas A Perkins
Title Professor Electrical
Engineering.