

II LOW FREQUENCY OSCILLATOR

A T H E S I S
submitted by

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- P R E F A C E -

This paper was prepared under the direction of Dr. C. A. Perkins and submitted as a thesis for a degree of Bachelor of Science in Electrical Engineering. It discusses the theory of a three electrode vacuum tube used as an a.c. power generator; the construction, calibration, and operation of a three electrode vacuum tube generator of low frequency oscillations, frequencies varying from *200* to *300* cycles per second.

Three electrode vacuum tubes are used extensively in radio and telephone work as generators of high frequencies, ranging from approximately 500 to 2000 kilocycles per second. For telegraphy low frequencies are used and by a key properly introduced in the grid circuit the oscillations may be started and stopped and thus the telegraphic signals made. A small oscillating vacuum tube is used extensively in laboratories where a few watts of a.c. power are required and where it is necessary to adjust the frequency to any desired degree such as power for bridge measurements, and in combination with a telephone receiver it is invaluable as a measurement of sound. The efficiency of a vacuum tube generator is very low, ranging from 25 to 50%. However, where small

amounts of power are required at or above ten kilocycles frequency a vacuum tube generator is always used as it is the simplest method of generating power at these frequencies. Above one hundred kilocycles frequency the vacuum tube has no competition as a generator due to the fact that the frequency may be varied so easily.

The purpose in mind when this thesis was started was to build a three-electrode vacuum generator that would oscillate at frequencies varying from five hundred to one thousand cycles per second. The oscillating circuit was to be made with fixed inductance and variable capacity and connected to headphones so that the sound of the oscillations could be heard and the oscillator be calibrated by sound. Therefore the primary object was to make an oscillator which could be used to measure the frequencies of other circuits of low frequency by sound resonance.

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tive side of a B battery. The plate current is passed through the coil F which is coupled to coil L so that the mutual inductance is such as to increase the grid potential as the plate current increases and the change in grid potential will be much greater. When the grid potential is reversed the effects will be reversed. The circuit L C is the oscillating circuit. L is inductance coil coupled with coil M and C is a condenser. Energy is fed into the oscillating circuit by the plate circuit through the coil F. If more energy is fed into the circuit than is used up in heating or similar losses, the circuit L C will oscillate, that is, send a current from L to C and from C back to L until all the energy is used. The current in L C will increase until it uses all the energy supplied to it by the plate circuit. The frequency of the oscillations depends on the relative values of the inductance of L and the capacity of C. Approximately the frequency, $f = \frac{10^6}{2\pi\sqrt{LC}}$ where L is in micro-henries and C in microfarads. These oscillations supply the grid with an alternating voltage and thus the plate current is alternately opposed and aided and audible sounds will be made in the phones if the frequency is not above audio-frequency.

GENERAL THEORY.

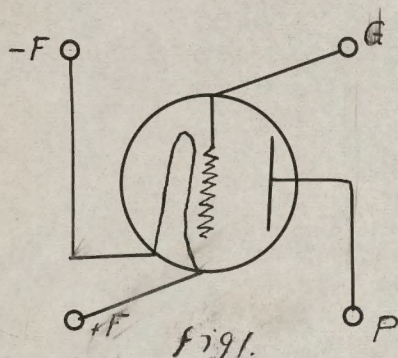


Figure one represents the three electrode vacuum tube. F is the filament which is a fine carbon or tungsten wire. P is the plate which is some conducting metal which is made around the filament and grid. G is the grid which is a network of wire or wire mesh that is placed between the filament and plate. The theory is that when the filament is heated by passing a current through it it emits electrons. If the plate is charged positive the electrons emitted from the filament will go from the filament to the plate and cause a plate-filament current. This current must pass through the grid as it is interposed between the filament and plate. Now if the grid should be made positive it will aid the emission of electrons and thus increase the plate current while if it is made negative it will oppose the emission of electrons and thus decrease the plate current. Therefore if an alternating voltage should be applied to the grid it would alternately aid and oppose the plate current. If a set of phones is placed in the plate circuit, the plate made positive by a constant

voltage and the grid supplied with an alternating voltage from some source there will be a sound heard in the phones every time the plate current is stopped as it will be if the grid voltage is made the proper amount. The frequency of this sound will be the same as the frequency of the alternating voltage on the grid. If the frequencies are not more than two or three thousand cycles per second they may be heard in the phones as a shrill whistle, above approximately three thousand cycles per second the sounds are so rapid that the ear cannot hear them. The lower the frequency the lower the note produced in the phones and if it is low enough each individual sound may be counted.

An oscillator is a simple device which uses the vacuum tube to generate its own alternating grid voltage, being supplied with a constant voltage on plate and constant filament current.

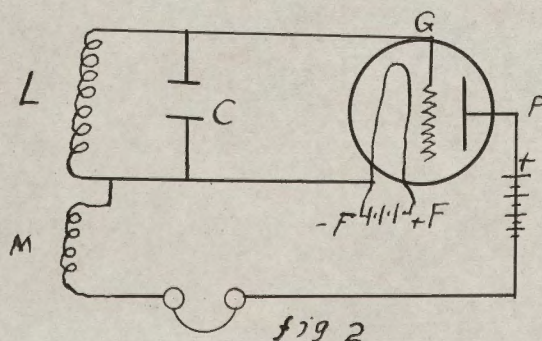


Figure 2 gives a diagram of how this may be done.

The filament is heated by a six volt battery and the plate is made positive by connecting it to the posi-

The inductance coils L and M may be a single coil wound in layers on a core with variable taps within the coil for varying the coupling; they may be two separate coils mounted one within the other so they can be turned relative to each other and the coupling be varied or mounted side by side and mounted so that the distance between them can be changed and thus the coupling changed, or the coils may be fixed relative to each other. There must be a variable condenser in the circuit for tuning the most of the capacity may be obtained by using fixed condensers if desired. Varying either the inductance or capacity of the oscillating circuit will vary the frequency. If the inductance and coupling of the coils are fixed as is the case with an audio transformer used as an inductance the frequency can be varied by the condensers above.

There are numerous hook-ups which may be used as oscillating circuits but diagrams of three of the simplest and most widely used are shown in figures three, four and five.

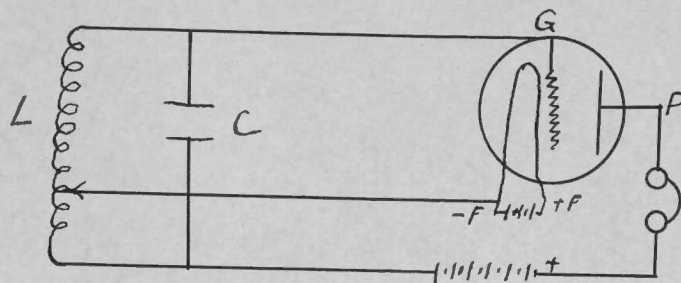


fig 3

Figure 3 is a Hartley auto feed back circuit in which the inductance is one coildwound on a single core with a variable coupling thus making the feed back coil a portion of the main coil. Figure four is a Hartley Parallel circuit using the auto feed back coil. Figure five is a regenerative feed back circuit. It can be used as a receiver of damped or undamped waves or as a generator of undamped waves.

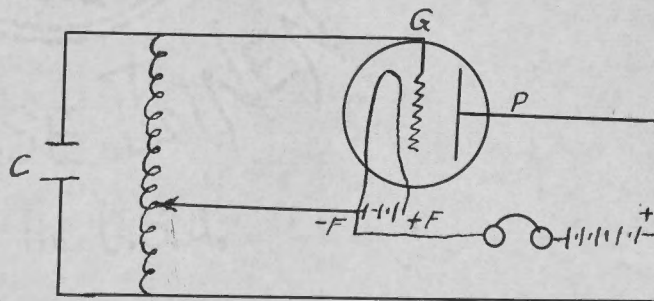


fig 4

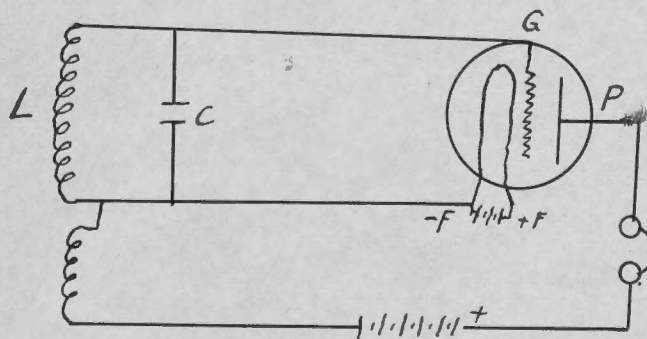


fig 5

DESCRIPTION OF METHOD AND APPARATUS USED.

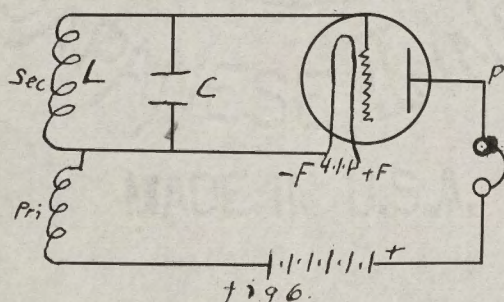
After a good bit of reading on the subject of oscillating circuits it was decided that test would be made with each of the three circuits diagramed in figures 3, 4, and 5, to decide which circuit was the most practical to use and which would give the best results. First the Hartley circuits as diagramed in figures three and four were tried. The first thing done was to decide on the capacities and calculate the inductance necessary to give the frequency desired. A fixed capacity of .06 microfarads and variable capacity of .005 microfarads was decided upon. Calculations were made for the amount of inductance needed to hold the frequency to one thousand cycles per second as a maximum. The first real difficulty arose when making the inductance coil was attempted. To get enough turns on a coil to have the required inductances and still have the coil a reasonable size it was necessary to hold the calculated amount of wire was made and mounted in a lathe and wound but the wire was so fine that it could not be wound in layers but soon became honeycombed and as a result when the spool was full there was not much over half the re-

-quired number of turns on it. More calculations were made with allowances made for honeycombing and the coil rewound. The next difficulty arose in trying to make a variable coupling between the two coils as they were wound on the same coil. After several methods were tried it was found that the best method was a slot cut in the spool radially from the center and the insulation scraped off the wires so that a sliding contact could be made to work in the slot and vary the coupling. However when this coil was connected up in the circuit it would not work satisfactorily, probably due to the fact that the coupling was bad, or there could have been bad contacts and connections.

The next method tried was using two coils in the Hartley circuit. The first difficulty arising was to find some way to vary the frequency the required amount. To make the variations by variable condensers was not deemed practical as it would take several condensers to vary the frequency any appreciable amount. Putting iron in the coils as a core was thought of and tried. By introducing the iron properly the frequency could be varied the required amount but it was found that for the same amount of

iron in the core the frequency varied considerably as the plate voltage varied, due to the magnetization of the core. Therefore it was not deemed advisable to use this method for producing the required frequency of oscillation.

The next method tried and the method used was an audio transformer hooked up as the regenerative circuit diagramed in figure 5. After a good bit of experimenting two 43 plate .001 microfarad variable condensers hooked in parallel were decided to be the best method of obtaining the required capacity and also the variation of the frequency.



A diagram of the hook up is shown in figure 6. The variable condensers were placed across the terminals of the secondary coil with

with one terminal going to the grid and the other going to the negative filament and to the primary coil which in turn is connected to the plate through a B battery and phones. A detailed diagram of the actual connections used in the construction of the oscillator is shown in figure 7. Figures 8, 9, 10, and 11 are photographs showing different views of the appa-

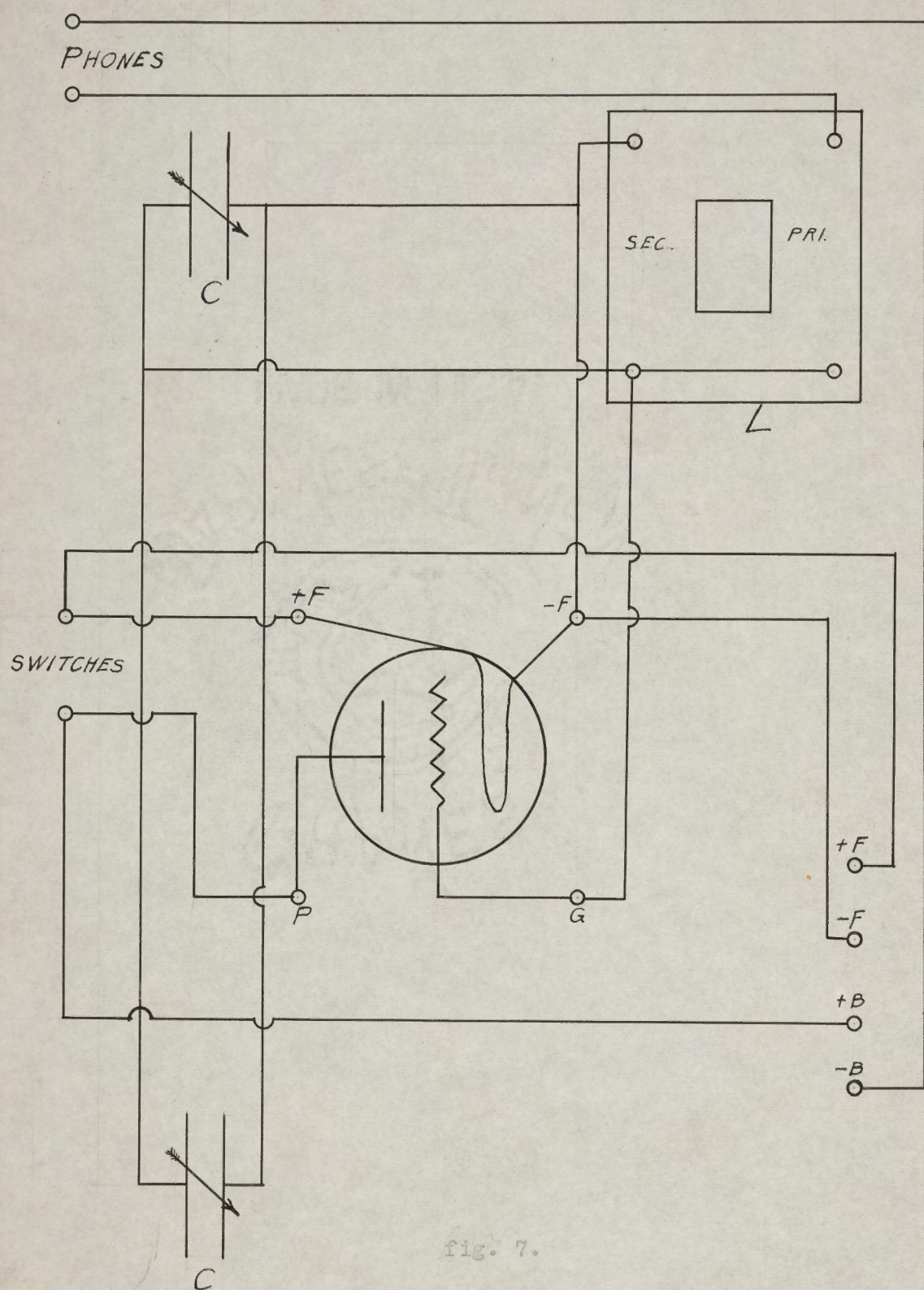


fig. 7.



fig. 8



fig. 9



fig. 10



fig. 11

ratus. All the wires were covered with insulation and connections that could not be screwed down tight were soldered.

The tube used was a Cunningham, CX - 301 - A, three electrode vacuum tube. The tubes are highly evacuated by exhausting the air with pumps. Mere exhaustion with pumps does not get all the air out as the sides of the tube and the metal surfaces hold some air in. To drive this air out the tubes are heated, while being exhausted, to a temperature higher than maximum operating temperature, therefore there are no atoms of air to oppose the emission of electrons and the ionization of the tube.

When the circuit was first hooked up it would not oscillate. A C battery was placed in the grid circuit but no effect was produced. Then a grid condenser and grid leak was tried and also a condenser was placed across the phones but no oscillations were produced. The plate voltage was varied but still no oscillations were produced. Accidentally during the course of connecting and reconnecting it was discovered that oscillations could be produced by disconnecting the condensers and inductance but having voltage on the plate, current in the filament, and holding the grid terminal between the fingers. The frequency was very low but the oscilla-

tions could be plainly heard. No reason for this phenomenon could be ascertained. Finally the connections of the primary of the transformer were reversed and the circuit began oscillating, producing a low note in the phones resembling the sound of a small motor boat. The set was then put together permanently placing the filament and plate battery posts in back of condensers as shown in figure and the posts for the phones were placed in upper left hand corner of the panel.

After the set was put together and in operation it was found that the frequency varied as the plate voltage varied, the frequency being increased as the voltage decreased. This variation was probably due to the magnetization of the iron core in the transformer. This varying of the frequency with the voltage made it very difficult to calibrate the oscillator. The frequency was too low to be measured by a wave meter and too high to measure with a frequency counter. The only available method was to calibrate by tuning to resonance with the vibrations of a tuning fork. When the frequency of the oscillator was compared with the frequency of tuning forks it was quickly seen that the frequency of the oscillator current was very low.

For the calibration the two condenser dials were set at zero, that is at minimum capacity or

when all the plates were out and the frequency was a maximum and six volts were impressed on the plate from two B batteries connected in parallel. An adjustable resonance tube was adjusted to approximately the correct length for resonance and then the dial on left turned until the sound of the oscillations was in resonance with sound in the tube. The reading of the dial was noted and then another adjustment of the dial was made using the same length of tube as a check on the first reading. The readings were tabulated as in table 1 given below:

TABLE ONE

C	L	f
17	26	305
28	27	295
35	28	285
43	29	275
60	30	265
72	31	259
100	32	251
114	33	244
125	34	238
137	35	231
147	36	225
167	37	219

Temperature of room = 21°C

Diameter of tube = 5.9 CM

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The frequency was figured by following formulae and calculations,

$$V = 33127 + 60 t$$

where t is temperature in degrees centigrade and V is velocity of sound in air at t° temperature in centimeters per second.

$$V = 33127 + 21 \times 60$$

$$= 34387 \text{ cm per second}$$

$$Y = 4 (L + .7r)$$

y = wave length

L = length of tube in cm

r = radius of tube in cm

$$Y = 4 (L + .7 \times \frac{5.9}{2})$$

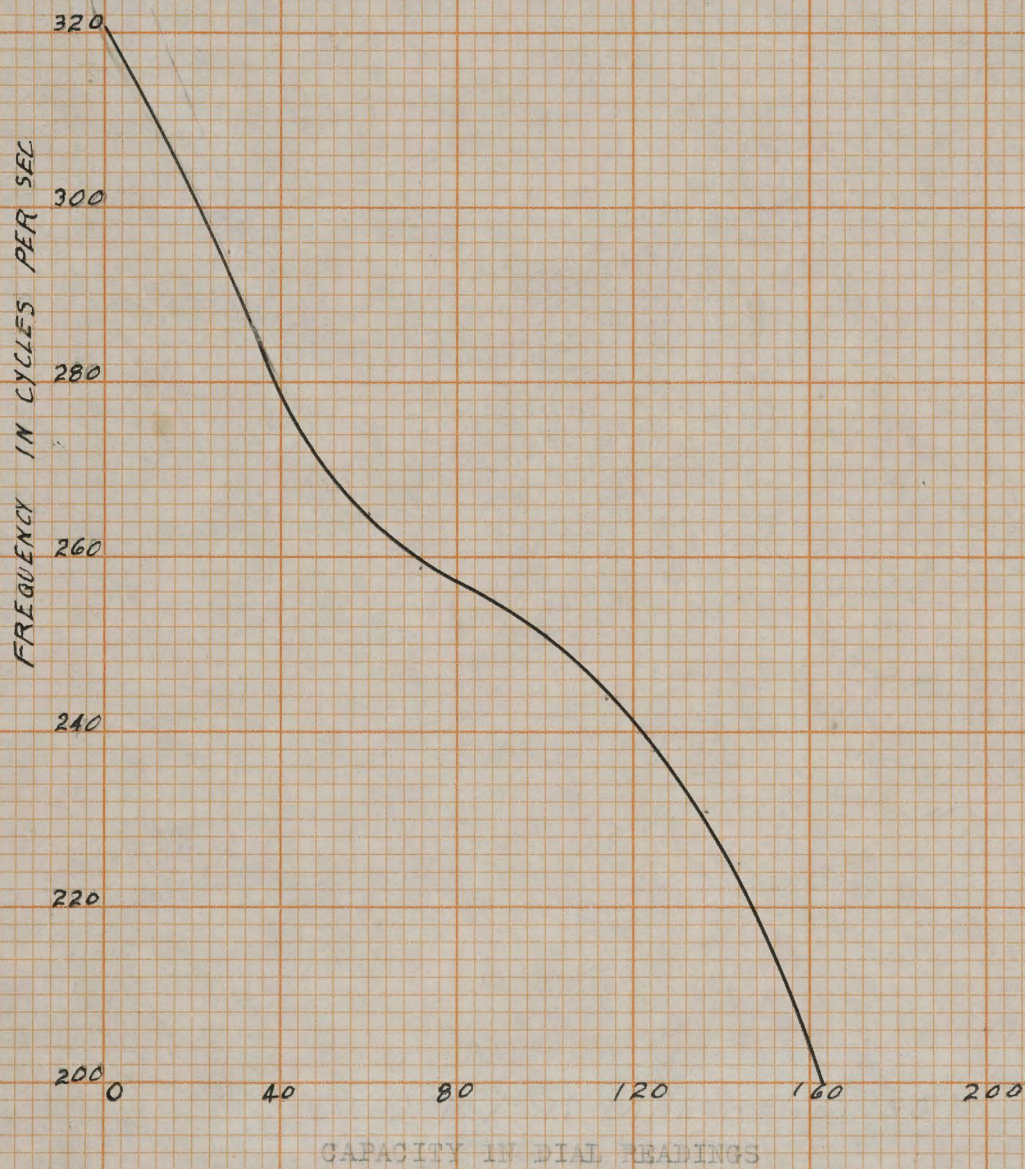
$$Y = 4 L + 8.62$$

$$f = \frac{V}{Y} \quad f = \text{frequency in cycles per sec.}$$

$$f = \frac{34387}{4L + 8.62}$$

$$f = \frac{8597}{L + 2.15}$$

From the data obtained a calibration curve was plotted with frequency as ordinates and dial readings as abscissae.



Due to the fact that the voltage varies the frequency there would be a slight variation of frequency from the frequency as shown by the curve but for a voltage at or near ~~six~~ the curve and frequencies are very nearly correct for they were checked by tuning the oscillator to resonance with two electric tuning forks of 100 and 200 cycles per second frequency.

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A P P R O V A L .

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.

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