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MAGNETIC LOSSES IN TRANSMISSION
LINE TOWERS HAVING A CLOSED
MAGNETIC
PATH SURROUNDING ONE CONDUCTOR

Thesis for the Degree of M. S.

Elias Morshed Sabbagh

1928

THESIS

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Title

Electrical engineering.

MAGNETIC LOSSES IN TRANSMISSION
LINE TOWERS HAVING A CLOSED MAGNETIC
PATH SURROUNDING ONE CONDUCTOR.

A Thesis Submitted to
The Faculty of the
MICHIGAN STATE COLLEGE

By
Elias Morshed Sabbagh

Candidate for the Degree
of
Master of Science.

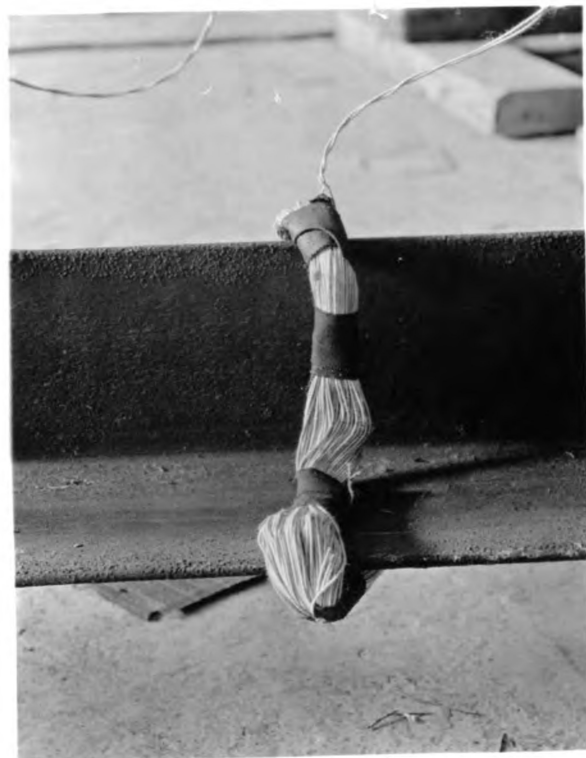
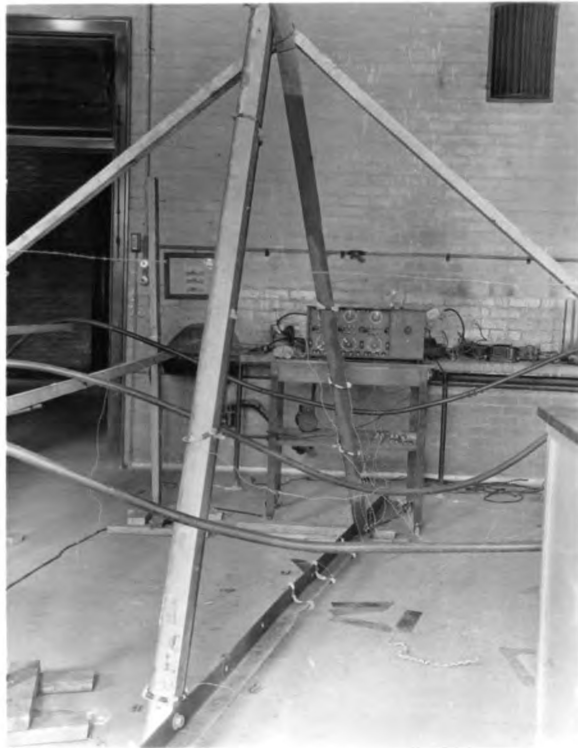
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THESIS

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The loop, line, and exploring coil.



INTRODUCTION

Many transmission lines have one conductor passing through a closed loop of structural steel. Such is generally the case of lines in hilly countries, or where three or more transmission line circuits are carried on the same tower structure due to high cost of right of way, of transposition towers for double circuits, etc.

Up to the present day it is customary in the design of a line, not to pay any attention to the magnetic losses in the towers, but for the sake of determining the facts we carried out such an investigation. Therefore, it is the purpose of this paper to investigate the losses in the loop and derive a formula by which it would be possible to compute the losses due to any current at any distance. Although those losses do not amount to a great deal in one single tower, they should be taken into consideration when the line is long and more particularly when it is under much load. The amount of magnetic losses then is not negligible.

The losses causing heating in the structure of substation are similar to the losses in the closed loop of the tower. At some points the heating is maximum as illustrated at various points of the legs of the loop.

ACKNOWLEDGMENT

The author desires to express his indebtedness to the Commonwealth Power Corporation of Michigan for furnishing the necessary tower parts, to the Board of Water and Electric Light of the City of Lansing for lending transformers and supplying cables capable of carrying high currents. The author wishes also to express his appreciation to the staff members of the Electrical Engineering Department of the Michigan State College for the suggestions and help received from them, and to Mr. F. Mitchell for his collaboration.

MAGNETIC LOSSES IN TRANSMISSION TOWERS HAVING A CLOSED MAGNETIC PATH SURROUNDING ONE CONDUCTOR

The Problem:

Many transmission lines have one conductor passing through a triangular, rectangular or polygonal closed magnetic path formed by the structural steel of the tower. It is the purpose of this paper to determine the amount of the iron losses in the tower caused by induction. The triangular shaped magnetic path was chosen as it is the most commonly used.

Procedure:

A triangular shaped loop of structural steel was erected. A three phase transmission circuit was built. One conductor of the line went through the center of the loop, while the two other conductors were on the right and left side. The three conductors were in the same horizontal plane and at the same distance from the steel.

Many exploring coils of known number of turns were wound around the three legs of the loop at intervals. The induced voltage in each coil was measured and recorded. By this means the fluxes induced in the loop at different points due to different currents were calculated. By using Steinmetz' and the eddy current formulae the different losses were calculated and graphs plotted.

Apparatus used:

Due to the limitation in the available apparatus many schemes were planned for obtaining enough current in the line and for measuring the

the first of these is the fact that the system is not a simple one, but a complex one, in which the various parts are interrelated and interdependent. The second is that the system is not a static one, but a dynamic one, in which the various parts are constantly changing and evolving. The third is that the system is not a closed one, but an open one, in which the various parts are constantly interacting with the environment. The fourth is that the system is not a linear one, but a non-linear one, in which the various parts are constantly interacting with each other in a non-linear fashion. The fifth is that the system is not a deterministic one, but a probabilistic one, in which the various parts are constantly interacting with each other in a probabilistic fashion. The sixth is that the system is not a simple one, but a complex one, in which the various parts are interrelated and interdependent. The seventh is that the system is not a static one, but a dynamic one, in which the various parts are constantly changing and evolving. The eighth is that the system is not a closed one, but an open one, in which the various parts are constantly interacting with the environment. The ninth is that the system is not a linear one, but a non-linear one, in which the various parts are constantly interacting with each other in a non-linear fashion. The tenth is that the system is not a deterministic one, but a probabilistic one, in which the various parts are constantly interacting with each other in a probabilistic fashion.

losses. It was first thought that by means of current transformers it would be possible to obtain any desired current in the line. The secondary coils of three transformers were used as primaries, and the primary sides were connected to the line. Although a large amount of current was flowing in the secondaries (used as primaries) of the current transformers not enough current appeared in the line. This scheme was rejected after trying each of the following connections, Delta-Delta, Wye-Wye, Delta-Wye, and Wye-Delta. Another set of current transformers was used but satisfactory results were not obtained.

A constant current transformer core was available in the laboratory. On it were mounted five coils designed to stand 5000 volts when in series. The core has three legs. It was planned to use one coil on each leg and the whole as a three phase transformer. The secondary being formed by winding two turns of the cable around each leg.

This scheme was tried, about 1000 volts being applied on one coil of the primary. Enough current passed ⁱⁿ the secondary line. The 1000 volts were obtained through a step up single phase transformer belonging to the laboratory. Two other similar transformers were necessary. Furthermore, they must be designed to carry 10 amps or their high voltage sides, as it takes 10 amps to energize the three phase coil and give the required current in the line. No transformers were found which could meet the requirements.

It was then found necessary to build a special transformer. The three legged core was used. Forty-five turns of No. 13 cable on each leg constituted the primary coils of the transformer and two turns of the line cable the secondary coils. The connection was made a Wye-Wye.

To change the current in the line the applied voltage was changed by changing the field of the supply alternator in the laboratory. The speed was always kept constant giving a constant frequency of 60 cycles.

The current in the line was measured by a step down current transformer. The free end of the line was short circuited to give the different high currents.

It was then necessary to find out a means to measure the voltages induced in the coils. The voltages induced in a one hundred turn coil was estimated not to exceed 1.5 volts. Low A.C. voltmeters were not available and those found on the market did not satisfy the requirements due to their low resistance. Voltmeters with high resistances allowing but a fraction of an ampere to flow in them was necessary, on account of the back ampere-turns which tend to oppose the inducing flux.

A.C. galvanometers or vacuum tube voltmeters could have been used if available.

All meters were shielded to protect their coils against the direct effect of magnetic lines around the conductors. Furthermore, the leads to the measuring instruments were run perpendicularly to the conductors and for more safety, twisted around each other.

An oscillograph was used to measure the induced voltage. The wave on each vibrating element was examined and when found to be sinusoidal was accurately measured. To measure the wave it was included between two boundaries of light projected by the two other elements thus giving twice its maximum value. The distance between the two lines was then measured and recorded. The oscillograph was calibrated at different intervals, using the same leads as those used to record the wave.

Thus with the instruments available in the department it was possible to perform the tests and get accurate results.

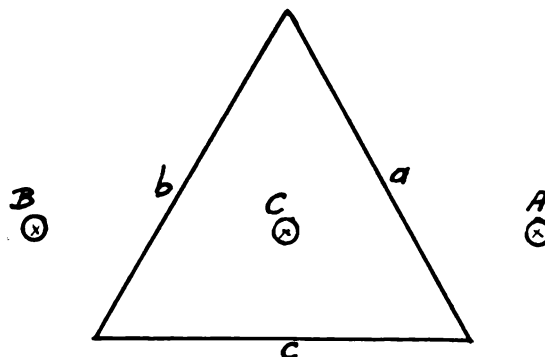
In regard to the exploring coils, it was first thought possible to use some coils available in the department. When tried it was found that a large voltage was induced in the coils, much larger than was expected. It was discovered that this voltage was largely due to a direct induction from the line to the coils. Two similar coils were then used. One was put around a steel leg and the other outside of it. The two were under similar conditions with respect to the line. They were connected so as to oppose each other. The oscillograph was then used to register the difference in voltages, viz. the voltage due to the flux in the iron tower. This was found to be small.

Due to the fact that at different points on each leg the flux varies, it was decided to build very narrow exploring coils so as to give voltages in a narrow piece of steel. On the other hand, due to the direct induction from the line, the exploring coils were wound as thin as possible.

In this test the coils were wound with one hundred turns of very thin wire (B. & S. No. 27). They were then put around the legs of the loop and given the same shape, viz., they were bound in the contour of the legs. In this manner the influence of the flux from the lines was reduced to a minimum.

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By examining the figure it is clearly seen that the fluxes in the three legs were unequal. Furthermore, as will be shown later, the flux in c was smaller than either that in a or b. On the other hand, due to the symmetry of the figure, when under balanced load the number of lines in a and b were equal.



From another point it was assumed throughout this test that leg a shielded both legs b and c against the magnetic effect of the current flowing in conductor a and that leg b shielded both legs a and c against the current flowing in b. Thus the flux induced in leg c is due to conductor c only while that in a and b is due to a and c, and b and c respectively. The necessity for using different exploring coils at different points along the legs is seen from the fact that the flux was not uniform in any leg. This will be mathematically proven later.

Consider one leg a and let us study the magnetic effect in a due to current flowing in lines a and c.

CM is perpendicular and bisects the leg. ($cy = 1/2 CQ$).

AP is another perpendicular from a.

If the effect of c alone is considered, the maximum flux would be at point M, according to the formula

$$B = \frac{1}{4\pi} \frac{2I}{r} \text{ lines per square centimeter}$$

where r is the distance in centimeters, I the current in amperes, and

μ the permeability.

If the effect of a is considered, maximum flux is at P.

Due to the fact that both fluxes are aiding and that R is at same distance from a and c the maximum flux would be at R.

It is to be noted that the flux at P0 is largely due to currents in a . At O the flux is small.

At Q the flux is mostly due to c and is nearly equal to that on the corners of leg c .

That point P does not fall on O can be proven as follows:

$AP = CM$, being perpendicular and conductors a and c are at the same distance from QO.

We further have for the same reason $CM = CY = AP = aS$

If P falls at O then $aO = aS$. Therefore aO is perpendicular to YS and QO or in triangle aOS

$$aS = aO$$

$$\text{Angle } aSO = aOS = 90^\circ \text{ which is impossible.}$$

Therefore, P cannot fall on O, viz. the perpendiculars drawn from the outside conductors do not fall at the joints of the legs.

The value of z in terms of r is found as follows:

$$QM = r \tan 60$$

$$= r \sqrt{3}$$

$$= 1.73205 r$$

$$MR = r \tan 30$$

$$= r \sqrt{\frac{1}{3}}$$

$$= 0.57735 r$$

$$MP = 2 MR$$

$$= 1.1547 r$$

$$QP = 1.73205 r + 1.547 r$$

$$= r [2.88675]$$

$$Z = \sqrt{(2.88675 r)^2 + r^2}$$

$$= r [\sqrt{9.333}]$$

$$= 3.05504 r$$

To find g in terms of r

$$Po = QM - MP$$

$$= 1.73205 r - 1.1547 r$$

$$= .57735 r$$

$$\therefore g = \sqrt{r^2 + (.57735 r)^2}$$

$$= 1.1547 r$$

$$am = CP = \frac{\sqrt{4r^2 + r^2}}{3}$$

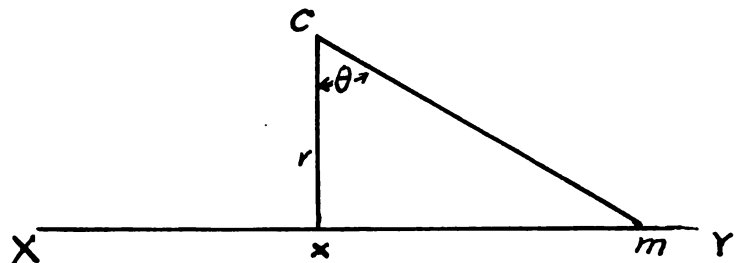
$$= r \sqrt{\frac{7}{3}}$$

$$= 1.5275 r$$

$$CR = Ra = \frac{r}{\cos 30}$$

$$= 1.1547$$

Consider now this other figure. The flux at any point along XY can be found in terms of the flux at x and the angle θ . The flux at x is



$$B = \mu \frac{.2 I}{r}$$

• $\frac{1}{2} \times \frac{1}{2} = \frac{1}{4}$

• $\frac{1}{2} \times \frac{1}{4} = \frac{1}{8}$

• $\frac{1}{4} \times \frac{1}{4} = \frac{1}{16}$

• $\frac{1}{4} \times \frac{1}{8} = \frac{1}{32}$

•

• $\frac{1}{8} \times \frac{1}{8} = \frac{1}{64}$

• $\frac{1}{8} \times \frac{1}{16} = \frac{1}{128}$

• $\frac{1}{16} \times \frac{1}{16} = \frac{1}{256}$

• $\frac{1}{16} \times \frac{1}{32} = \frac{1}{512}$

•

• $\frac{1}{32} \times \frac{1}{32} = \frac{1}{1024}$

• $\frac{1}{32} \times \frac{1}{64} = \frac{1}{2048}$

• $\frac{1}{64} \times \frac{1}{64} = \frac{1}{4096}$

•

• $\frac{1}{64} \times \frac{1}{128} = \frac{1}{8192}$

• $\frac{1}{128} \times \frac{1}{128} = \frac{1}{16384}$

• $\frac{1}{128} \times \frac{1}{256} = \frac{1}{32768}$

• $\frac{1}{256} \times \frac{1}{256} = \frac{1}{65536}$

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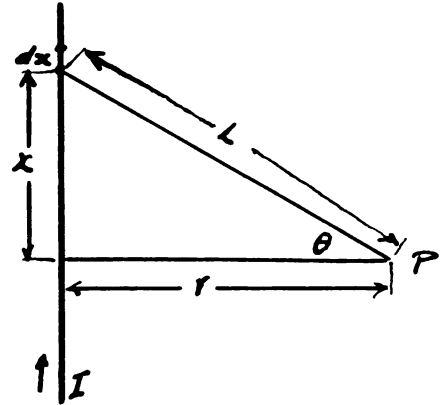
At m it is

$$\begin{aligned}
 B_m &= \mu \frac{.2 I}{Cm} \\
 &= \mu \frac{.2 I \cos \theta}{r} \\
 &= B_x \cos \theta
 \end{aligned}$$

Theoretical solution:

Assume a conductor carrying a current I abamperes flowing as shown in the figure.

It is required to know the magnetic intensity at a point P outside of that conductor.



To solve this problem consider

an element of length dx at distance L centimeters from P . By Coulomb's law the effect of that element on a point L centimeters away is

$$dH = \frac{I dx}{L^2} \cos \theta$$

Therefore the effect of the total wire is

$$H = \int_{-\infty}^{+\infty} \frac{I \cos \theta}{L^2} dx$$

assuming the conductor to be very long.

From the figure we have

$$x = r \tan \theta$$

Therefore

$$dx = r \sec^2 \theta d\theta$$

Also

$$L = \frac{r}{\cos \theta}$$

Inserting these values in the above expression

$$H = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{I \cos \theta r \sec^2 \theta d\theta}{\frac{r^2}{\cos^2 \theta}}$$

This becomes

$$H = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{I \cos \theta}{r} d\theta$$

$$H = \frac{I}{r} [\sin \theta]_{-\frac{\pi}{2}}^{\frac{\pi}{2}}$$

$$= \frac{2 I}{r}$$

If I is in amperes

$$H = \frac{2 I}{r} \quad \text{gausses}$$

If the point P is in a material having μ permeability

$$B = \mu \frac{2 I}{r} \quad \text{lines per square centimeter}$$

This is one of the fundamental formula applicable here.

In alternating current if the waves are sinusoidal and time properly chosen the current at any instant may be expressed as

$$i = I_{\max} \sin w t$$

where w is the angular velocity

$$w = 2\pi f$$

and t the time in seconds.

The instantaneous current i produces a flux Q . Due to the fact that i is varying Q is varying too. In any material which has a constant permeability the flux wave has the same shape as the current wave. Due to the fact that the flux density in the tower legs is low it can be assumed that the permeability of the steel within the boundaries used is constant and therefore the flux wave is sinusoidal.

$$\text{Therefore} \quad Q = Q_m \sin w t$$

$$\text{It was seen that} \quad Q = \mu \frac{2 I}{r} \Delta$$

where Δ is cross section area.

$$\text{Therefore} \quad Q_m = \mu \frac{2 I_m}{r} \Delta$$

$$Q_{t-o} = C \frac{.2 I_m}{r} \left[\frac{\sin wt}{1.1547} - \frac{\sin (wt + 240)}{2} \right]$$

Similarly the fluxes at P, R, M and Q are respectively

$$Q_{t-P} = C \frac{.2 I_m}{r} \left[\sin wt - \frac{\sin (wt + 240)}{1.5275} \right]$$

$$Q_{t-R} = C \frac{.2 I_m}{1.1547 r} \left[\sin wt - \sin (wt + 240) \right]$$

$$Q_{t-M} = C \frac{.2 I_m}{r} \left[\frac{\sin wt}{1.5275} - \sin (wt + 240) \right]$$

$$Q_{t-Q} = C \frac{.2 I_m}{r} \left[\frac{\sin wt}{3.05504} - \frac{\sin (wt + 240)}{2} \right]$$

On the other hand

$$e = -N \frac{dQ}{dt} 10^{-8}$$

Therefore

$$\begin{aligned} e_o &= -NC \frac{.2 I_m}{r} 10^{-8} \frac{d}{dt} \left[\frac{\sin wt}{1.1547} - \frac{\sin (wt + 240)}{2} \right] \\ &= -NC \frac{2 I_m}{r} 10^{-9} \left[\frac{w \cos wt}{1.1547} - \frac{w \cos (wt + 240)}{2} \right] \\ &= -K \left[\frac{\cos wt}{1.1547} - \frac{\cos (wt + 240)}{2} \right] \end{aligned}$$

where

$$\begin{aligned} K &= NC \frac{2 I_m}{r} 10^{-9} w \\ e_o &= -K \left[\frac{\cos wt}{1.1547} - \frac{\cos wt \cos 240 - \sin wt \sin 240}{2} \right] \\ &= -K [.866 \cos wt + .25 \cos wt - .433 \sin wt] \\ &= -K [1.116 \cos wt - .433 \sin wt] \end{aligned}$$

Its maximum value occurs when

$$-1.116 \sin wt = .433 \cos wt$$

$$\tan wt = - .388$$

$$wt = 158^\circ 45'$$

and minimum when

$$wt = -21^\circ 15'$$

Its minimum is then

$$e_{om} = -K [1.116 \times .93201 + (.433 \times .36244)]$$

$$\begin{aligned} e_{om} &= -K [1.04012 + .156936] \\ &= -1.19705 K \end{aligned}$$

and its maximum

$$\begin{aligned} e_{om} &= -K [1.116 \times (-.93201) - (.433 \times .36244)] \\ &= + 1.19705 K \end{aligned}$$

Similarly

$$\begin{aligned} e_p &= -K \left[\cos wt - \frac{\cos (wt + 240)}{1.5275} \right] \\ &= -K [\cos wt + .327233 \cos wt - .56693 \sin wt] \\ &= -K [1.327 \cos wt - .566 \sin wt] \end{aligned}$$

Its minimum occurs when

$$\begin{aligned} \tan wt &= -.42652 \\ wt &= -23^\circ 6' \end{aligned}$$

Its maximum when

$$wt = 156^\circ 54'$$

It is then

$$\begin{aligned} e_{om} &= +K [1.327 \times .91982 + .566 \times .39234] \\ &= K [1.2206 + .22206] \\ &= 1.4426 K \\ e_s &= -K [.866 \cos wt + .433 \cos wt - .75 \sin wt] \\ &= -K [1.299 \cos wt - .75 \sin wt] \end{aligned}$$

Its maximum value occurs when

$$\begin{aligned} \tan wt &= -.577 \\ wt &= 150 \end{aligned}$$

It is then

$$\begin{aligned} e_{RM} &= K [1.299 \times .86603 + .75 \times .5] \\ &= [1.1249 + .375] K \\ &= 1.5 K \end{aligned}$$

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Therefore the total flux at O' is

$$Q_{t-O'} = Q_{a-O'} - Q_{c-O'}$$

$$Q_{t-O'} = C \frac{.2 I_m}{r} \left[\frac{\sin (wt + 120)}{1.1547} - \frac{\sin (wt + 240)}{2} \right]$$

Similarly the flux is at P', R', M' and Q are respectively

$$Q_{t-P'} = C \frac{.2 I_m}{r} \left[\sin (wt + 120) - \frac{\sin (wt + 240)}{1.5275} \right]$$

$$Q_{t-R'} = C \frac{.2 I_m}{r} \frac{1}{1.1547} [\sin (wt + 120) - \sin (wt + 240)]$$

$$Q_{t-M'} = C \frac{.2 I_m}{r} \left[\frac{\sin (wt + 120)}{1.5275} - \sin (wt + 240) \right]$$

$$Q_{t-Q} = C \frac{.2 I_m}{r} \left[\frac{\sin (wt + 120)}{3.05504} - \frac{\sin (wt + 240)}{2} \right]$$

Consequently

$$e_{O'} = -NC \frac{.2 I_m}{r} 10^{-8} \frac{d}{dt} \left[\frac{\sin (wt + 120)}{1.1547} - \frac{\sin (wt + 240)}{2} \right]$$

$$= -NC \frac{.2 I_m}{r} 10^{-9} w \left[\frac{\cos (wt + 120)}{1.1547} - \frac{\cos (wt + 240)}{2} \right]$$

$$= -K [.866 \cos (wt + 120) - .5 \cos (wt + 240)]$$

$$= -K [.866 (-.5 \cos wt - .866 \sin wt) - .5 (-.5 \cos wt + .866 \sin wt)]$$

$$= K [.433 \cos wt + .75 \sin wt - .25 \cos wt + .433 \sin wt]$$

$$= K [.183 \cos wt + 1.183 \sin wt]$$

It has its maximum when

$$.183 \sin wt = 1.183 \cos wt$$

$$\tan wt = \frac{1.183}{.183}$$

$$= 6.464$$

$$wt = 81^\circ 12.6'$$

It is then

$$\begin{aligned} e_{x_0} &= K [.183 \times .15281 + 1.183 \times .98825] \\ &= K [.02796 + 1.16909] \\ &= K [1.19705] \end{aligned}$$

Similarly

$$\begin{aligned} E_{p_1} &= -K \left[\cos (wt + 120) - \frac{\cos (wt + 240)}{1.5275} \right] \\ &= K \left[.5 \cos wt + .866 \sin wt - \frac{.5 \cos wt - .866 \sin wt}{1.5275} \right] \\ &= K [.5 \cos wt + .866 \sin wt - .327233 \cos wt + .56693 \sin wt] \\ &= K [172767 \cos wt + 1.33293 \sin wt] \end{aligned}$$

It has its maximum when

$$.173 \sin wt = 1.3332 \cos wt$$

$$\tan wt = 7.7151$$

$$wt = 82^\circ 36'.4$$

It is then

$$\begin{aligned} E_{MP} &= K [.173 \times .12870 + 1.3329 \times .99168] \\ &= K [.0222651 + 1.32191] \\ &= K [1.344175] \\ E_R &= -K [.866 \cos(wt + 120) + .433 \cos wt - .75 \sin wt] \\ &= -K [.866 (-.5 \cos wt - .866 \sin wt) + .433 \cos wt - .75 \sin wt] \\ &= K [.433 \cos wt + .75 \sin wt - .433 \cos wt + .75 \sin wt] \\ &= K [1.5 \sin wt] \end{aligned}$$

This is maximum when

$$\sin wt = 1$$

$$wt = 90$$

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Figure 1. The effect of the concentration of the polymer on the surface energy of the polymer-coated glass slides. The surface energy of the polymer-coated glass slides was measured by the contact angle of water. The surface energy of the polymer-coated glass slides was measured by the contact angle of water. The surface energy of the polymer-coated glass slides was measured by the contact angle of water.

1. *Journal of the American Medical Association*, 1997; 278: 1039-1044.

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1. *Journal of the American Medical Association*, 1990; 263: 1025-1028.

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• *Journal of the American Medical Association*, 1997; 277: 1025-1026

1. *Journal of the American Medical Association*, 1990; 263: 1025-1028.

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| Condition | Control (n=10) | MCI (n=10) | AD (n=10) |
|-----------|----------------|------------|-----------|
| A | ~95% | ~85% | ~75% |
| B | ~95% | ~85% | ~75% |
| C | 100% | 80% | 60% |
| D | ~95% | ~85% | ~75% |

• **1997** – **1998**

It is then

$$E_{MR} = 1.5 K$$

$$\begin{aligned} e_{t-M} &= -K \left[\frac{\cos (wt + 120)}{1.5275} - \frac{\cos (wt + 240)}{2} \right] \\ &= K [.6546 (.5 \cos wt + .866 \sin wt) - .5 \cos wt + .866 \sin wt] \\ &= K [.3273 \cos wt + .5668 \sin wt - .5 \cos wt + .866 \sin wt] \\ &= K [1.4328 \sin wt - .1727 \cos wt] \end{aligned}$$

This is maximum when

$$1.4328 \cos wt + .1727 \sin wt = 0$$

$$\tan wt = -8.2964$$

$$wt = 96^\circ 52.4'$$

It is then

$$\begin{aligned} e_{mR} &= K [1.4328 \times .99281 + .1727 \times .11968] \\ &= K [1.42249 + .02066] \\ &= K [1.44315] \\ E_Q &= -K \left[\frac{\cos (wt + 120)}{3.05504} - \frac{\cos (wt + 240)}{2} \right] \\ &= K [.3273 (.5 \cos wt + .866 \sin wt) + .5 (-.5 \cos wt + .866 \sin wt)] \\ &= K [.16365 \cos wt + .28344 \sin wt - .25 \cos wt + .433 \sin wt] \\ &= K [-.08635 \cos wt + .71644 \sin wt] \end{aligned}$$

This is maximum when

$$.08635 \sin wt + .71644 \cos wt = 0$$

or

$$\tan wt = -8.296$$

$$wt = 96^\circ 52.4'$$

Its value is then

$$\begin{aligned} E_{mQ} &= K [.08635 \times .11968 + .71644 \times .99281] \\ &= K [.010334 + .711288] \\ &= K [.721622] \end{aligned}$$

Leg c

The flux at F is

$$\Phi_{c-F} = C \frac{.2 I_m}{r} \sin (wt + 240)$$

Therefore the voltage at F is

$$e_{c-F} = NC \frac{.2 I_m}{r} \omega \cos (wt + 240)$$

$$= -K \cos (wt + 240)$$

$$= -K [-.5 \cos wt + .866 \sin wt]$$

$$= K [.5 \cos wt - .866 \sin wt]$$

It has its maximum value when

$$-.5 \sin wt - .866 \cos wt = 0$$

$$\tan wt = -1.732$$

$$wt = 300$$

It is then

$$e_m = K [.5 \times .5 - (-.866 \times .866)]$$

$$= K$$

$$Fo = r \sqrt{3}$$

$$= 1.732 r$$

$$FE = .866 r$$

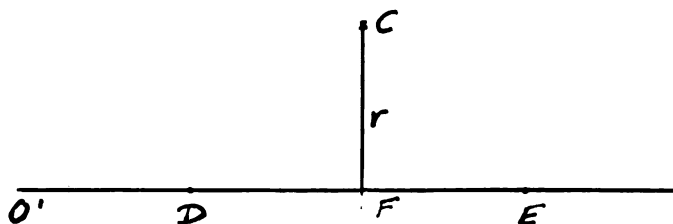
$$CE = \sqrt{r^2 + (.866 r)^2}$$

$$= r \sqrt{\frac{7}{4}}$$

$$= \frac{r}{2} \sqrt{7}$$

$$= \frac{r}{2} (2.6457) = 1.3228 r$$

$$e_{c-E} = K \left[\frac{.5 \cos wt}{1.3228} - \frac{.866}{1.3228} \sin wt \right]$$



$$= K [.3779 \cos wt - .6546 \sin wt]$$

It has its maximum when

$$wt = 300^\circ$$

It is then

$$\begin{aligned} e_{cE} &= K [.3779 \times .5 + (.6546 \times .866)] \\ &= K [.18895 + .56688] \\ &= .75583 K \end{aligned}$$

$$\begin{aligned} e_o &= K \left[\frac{.5 \cos wt}{2} - \frac{.866 \sin wt}{2} \right] \\ &= K [.25 \cos wt - .433 \sin wt] \end{aligned}$$

It has its maximum when

$$wt = 300$$

It is then

$$\begin{aligned} e_{m-o} &= K [.25 \times .50 + .433 \times .866] \\ &= K [.125 + .365] \\ &= K [.50] \\ &= .2235 K \end{aligned}$$

It is to be noticed that there is a phase angle between the different voltages at different points on the lower halves of legs a and b. This difference in the phase angle on the same leg is very small, being only 15° on legs a and b. The upper halves have the same angle or a very small difference in phase angle. This constancy in the angles shows that the flux in the upper halves is almost a pulsating flux, viz. it is largely due to the current in conductor c.

Leg c has no difference in its voltage phase angles at different points. The voltages along c are in phase.

On the other hand, the voltage is proportional to the flux, thus

$$Q_m = DV$$

Therefore, the fluxes at different points is proportional to their voltages. The fluxes on leg a at o, P, R, M and Q are respectively

$$Q_{mo} = D [1.19705 \text{ K}]$$

$$Q_{mP} = D [1.4426 \text{ K}]$$

$$Q_{mR} = D [1.5 \text{ K}]$$

$$Q_{mM} = D [1.4431 \text{ K}]$$

$$Q_{mQ} = D [.7215 \text{ K}]$$

where D is a constant depending upon frequency and number of turns.

Similarly on leg b the fluxes at o', P', R', M', and Q' are respectively

$$Q_{mo'} = D [1.19705 \text{ K}]$$

$$Q_{mP'} = D [1.34475 \text{ K}]$$

$$Q_{mR'} = D [1.5 \text{ K}]$$

$$Q_{mM'} = D [1.44315 \text{ K}]$$

$$Q_{mQ'} = D [.7216 \text{ K}]$$

The average flux on a or b is

$$\begin{aligned} Q_m &= \frac{DK}{S} [1.19705 + 1.4426 + 1.5 + 1.4431 + .7215] \\ &= D [1.26085] \end{aligned}$$

On leg c

$$Q_{mo} = D [.2235 \text{ K}]$$

$$Q_{mE} = D [.75583 \text{ K}]$$

$$Q_{mF} = D [1.000 \text{ K}]$$

$$Q_{mD} = D [.75583 \text{ K}]$$

$$Q_{mo'} = D [.2235 \text{ K}]$$

$$Q_m = \frac{DK}{S} [2.95866]$$

$$= D [.59173 \text{ K}]$$

Therefore the flux in each of the legs a and b is about

$$\frac{1.26085}{.59173} \text{ times the flux in c}$$

or
$$Q_a = Q_b = 2.13 Q_c$$

The hysteresis losses in a and b are $(2.13)^{1.6}$ times those in c,

or
$$\begin{aligned} P_{ha} = P_{hb} &= (2.13)^{1.6} P_{hc} \\ &= 3.3528 P_{hc} \end{aligned}$$

The eddy current losses in a and b are each $(2.13)^2$ times those in c

$$\begin{aligned} P_{ea} = P_{eb} &= (2.13)^2 P_{ec} \\ &= 4.5369 P_{ec} \end{aligned}$$

If all the losses were due to hysteresis alone, the total losses in each of the legs a and b would have been

$$P_{ta} = P_{tb} = 3.3528 P_{hc}$$

viz. the losses in c would then be only $\frac{1}{7.7056}$ of the total losses or

about 13%.

If all the losses were due to eddy current alone, the total losses in each leg (a and b) would have been

$$P_{ta} = P_{tb} = 4.5369 P_{tc}$$

viz. the losses in c would then be $\frac{1}{10.0738}$ of the total losses or about

10%.

The actual losses in c are between those two values, viz. between 10 and 13% while from 43 to 45% of the total will be the losses in each of the legs a and b.

Leg c was not shielded by any line. Under present conditions the values of voltages at different points on leg c are different from what

was found previously. To calculate these voltages procede as follows:

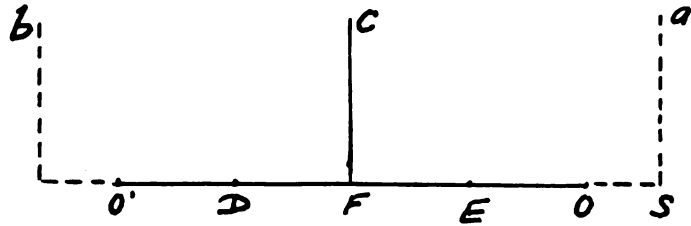
$$A_0 = 1.1547 r$$

$$S_0 = .57735 r$$

$$E_0 = .866$$

$$C_0 = 2 r$$

$$CE = 1.3228 r$$



Therefore

$$\begin{aligned} AE &= \sqrt{r^2 + (1.443 r)^2} \\ &= r \sqrt{1 + 2.082249} \\ &= 1.755 r. \end{aligned}$$

$$\begin{aligned} AF &= \sqrt{r^2 + (.57735 + 1.732)^2 r^2} \\ &= r \sqrt{1 + 5.331481} \\ &= 2.516 r. \end{aligned}$$

$$\begin{aligned} AD &= r \sqrt{1 + (.57735 + 2.598)^2} \\ &= r \sqrt{1 + 10.080625} \\ &= 3.33 r. \end{aligned}$$

$$\begin{aligned} AO' &= r \sqrt{1 + (.57735 + 3.464)^2} \\ &= r \sqrt{1 + 16.329681} \\ &= 4.163 r. \end{aligned}$$

$$Q_0 = C \left[\frac{\sin wt}{1.1547} + \frac{\sin (wt + 120)}{4.163} + \frac{\sin (wt + 240)}{2} \right]$$

$$Q_E = C \left[\frac{\sin wt}{1.775} + \frac{\sin (wt + 120)}{3.33} + \frac{\sin (wt + 240)}{1.3228} \right]$$

$$Q_F = C \left[\frac{\sin wt}{2.516} + \frac{\sin (wt + 120)}{2.516} + \sin (wt + 240) \right]$$

$$Q_D = C \left[\frac{\sin wt}{3.33} + \frac{\sin (wt + 120)}{1.755} + \frac{\sin (wt + 240)}{1.3228} \right]$$

$$Q_{O'} = C \left[\frac{\sin wt}{4.163} + \frac{\sin (wt + 120)}{1.1547} + \frac{\sin (wt + 240)}{2} \right]$$

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• **Stress** – the body's response to a stimulus

1. *Journal of the American Medical Association*, 1997; 277: 1033-1038.

Therefore

$$\begin{aligned}
 e_o &= -K \left[\frac{\cos wt}{1.1547} + \frac{\cos (wt + 120)}{4.163} + \frac{\cos (wt + 240)}{2} \right] \\
 &= -K [.866 \cos wt + .2402 (\cos wt + 120) + .5 (\cos wt + 240)] \\
 &= -K [.866 \cos wt - .2403 (.5 \cos wt + .866 \sin wt) - .5 \\
 &\quad (.5 \cos wt - .866 \sin wt)] \\
 &= -K [.866 \cos wt - .1201 \cos wt - .2080 \sin wt - .25 \cos wt \\
 &\quad + .433 \sin wt] \\
 &= -K [.4959 \cos wt + .225 \sin wt]
 \end{aligned}$$

It has its maximum value when

$$\begin{aligned}
 .4959 \sin wt &= .225 \cos wt \\
 \tan wt &= .45372 \\
 wt &= 204^\circ 24.6'
 \end{aligned}$$

It is then

$$\begin{aligned}
 e_{om} &= K [.4959 \times .9106 + .225 \times .41326] \\
 &= K [.45165 + .09298] \\
 &= .54463 K. \\
 e_E &= -K \left[\frac{\cos wt}{1.755} + \frac{\cos (wt + 120)}{3.33} + \frac{\cos (wt + 240)}{1.3228} \right] \\
 &= -K [.5698 \cos wt + .3 \cos (wt + 120) + .7559 \cos (wt + 240)] \\
 &= -K [.5698 \cos wt + .3 (-.5 \cos wt - .866 \sin wt) + .7559 \\
 &\quad (-.5 \cos wt + .866 \sin wt)] \\
 &= -K [.5698 \cos wt - .15 \cos wt - .2598 \sin wt - .37795 \cos wt \\
 &\quad + .65461 \sin wt] \\
 &= -K [.0419 \cos wt + .3948 \sin wt]
 \end{aligned}$$

This is maximum when

$$\begin{aligned}
 .0419 \sin wt &= .3948 \cos wt \\
 \tan wt &= 9.42243 \\
 wt &= 263^\circ 56.6'
 \end{aligned}$$

It is then

$$e_E = K [.0419 \times .1055 + .2948 \times .99442]$$

$$= K [.00442 + .39259]$$

$$= .39701 K$$

$$e_F = -K \left[\frac{\cos wt}{2.516} + \frac{\cos (wt + 120)}{2.516} + \cos (wt + 240) \right]$$

$$= -K [.3974 \cos wt + .3974 (-.5 \cos wt - .866 \sin wt) + (.5 \cos wt - .866 \sin wt)]$$

$$= -K [.3974 \cos wt - .1987 \cos wt - .344148 \sin wt - .5 \cos wt + .866 \sin wt]$$

$$= K [.3013 \cos wt - .522 \sin wt]$$

This is maximum when

$$-.3013 \sin wt = .522 \cos wt$$

$$\tan wt = - \frac{.522}{.3013}$$

$$\tan wt = - 1.7324$$

$$wt = 300$$

It is then

$$e_{Fm} = K [.3013 \times .5 + .522 \times .866]$$

$$= K [.15065 + .452052]$$

$$= K [.600702]$$

$$= .600702 K$$

$$e_D = -K \left[\frac{\cos wt}{3.33} + \frac{\cos (wt + 120)}{1.755} + \frac{\cos (wt + 240)}{1.3228} \right]$$

$$= -K [.3 \cos wt + .5698 \cos (wt + 120) + .755 \cos (wt + 240)]$$

$$= -K [.3 \cos wt + .5698 (-.5 \cos wt - .866 \sin wt) + .755 (-.5 \cos wt + .866 \sin wt)]$$

$$= -K [.3 \cos wt - .2849 \cos wt - .4934 \sin wt - .37795 \cos wt + .65461 \sin wt]$$

$$= K [.3629 \cos wt - .1612 \sin wt]$$

It has its maximum value when

$$-.3629 \sin wt = .1612 \cos wt$$

$$\tan wt = -.4442$$

$$wt = 336^{\circ} 3'$$

It is then equal to

$$e_{Dm} = K [.3629 \times .9139 + .1612 \times .40594]$$

$$= K [.33165 + .07543]$$

$$= .40708 K$$

$$e_o = -K \left[\frac{\cos wt}{4.163} + \frac{\cos (wt + 120)}{1.1547} + \frac{\cos (wt + 240)}{2} \right]$$

$$= -K [.2402 \cos wt + .866 \cos (wt + 120) + .5 \cos (wt + 240)]$$

$$= -K [.2402 \cos wt + .866 (-.5 \cos wt - .866 \sin wt) + .5 (-.5 \cos wt + .866 \sin wt)]$$

$$= -K [.2402 \cos wt - .433 \cos wt - .75 \sin wt - .25 \cos wt + .433 \sin wt]$$

$$= K [.4428 \cos wt + .317 \sin wt]$$

It is maximum when

$$.4428 \sin wt = .317 \cos wt$$

$$\tan wt = .7158$$

$$wt = 35^{\circ} 35.6'$$

It is then equal to

$$e_{om} = K [.4428 \times .81315 + .317 \times .58200]$$

$$= K [.36006 + .18449]$$

$$= .54455 K$$

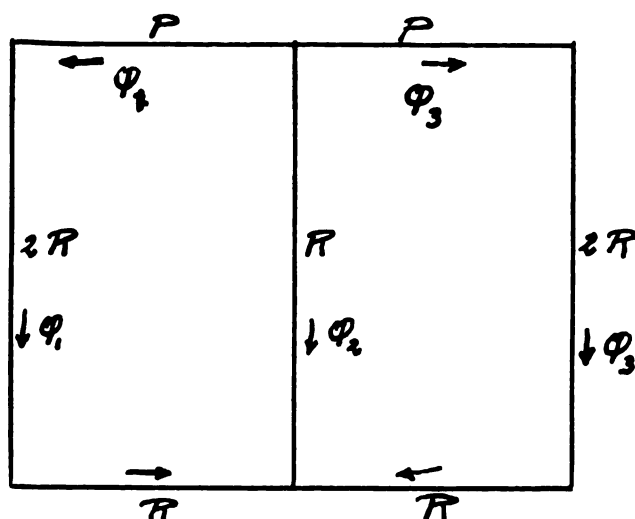
We thus see that under these conditions we have a rotating flux in leg c. The voltages at different points of the legs reach their maxima at different times. This was found to be true experimentally.

Reasons why losses in legs a and b are unequal.

Although due to symmetry the fluxes in legs a and b should be equal, in the test they were found to be unequal. This was due to the fact that the currents were not 120° apart as assumed in the theory. The impedances of the three current transformers were unequal in value and the fluxes in the potential transformer were not exactly 120° apart.

To prove this last statement

assume i_1 , i_2 , and i_3 to be the three instantaneous magnetizing currents, ϕ_1 , ϕ_2 , and ϕ_3 the instantaneous fluxes, $2R$ the reluctance of each one of the outside legs, R that of the inside leg, P and R the reluctances of each part of the yoke as shown in the figure.



Therefore

$$.4\pi n (i_1 - i_2) = (2R + R + P) \phi_1 - R\phi_2 \quad (1)$$

$$.4\pi n (i_3 - i_2) = (2R + R + P) \phi_3 - R\phi_2 \quad (2)$$

and
$$\phi_1 + \phi_2 + \phi_3 = 0$$

By adding
$$.4\pi n (i_1 + i_3 - 2i_2) = (2R + R + P)(\phi_1 + \phi_3) - 2R\phi_2 \quad (3)$$

and knowing that
$$i_1 + i_2 + i_3 = 0$$

therefore
$$i_1 + i_2 = -i_3$$

and by substitution we get

$$.4\pi n (-3i_2) = (2R + R + P) (-\phi_2) - 2R\phi_2$$

$$.4\pi n (3i_2) = \phi_2 (4R + R + P)$$

1. The first part of the document is a list of the names of the persons who were present at the meeting. The names are listed in alphabetical order.

2. The second part of the document is a list of the topics that were discussed at the meeting. The topics are listed in alphabetical order.

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Therefore
$$.4\pi n i_2 = \frac{4R + R + P}{3} Q_2 \quad (3)$$

Equation (3) shows that the flux Q_2 is in phase with the magnetizing current i_2 in the middle leg.

Substituting (3) in (1) we get

$$.4\pi n i_1 - \frac{4R + R + P}{3} Q_2 = (2R + R + P) Q_1 - RQ_2$$

which becomes

$$.4\pi n i_1 = (2R + R + P) Q_1 + \frac{R + R + P}{3} Q_2 \quad (4)$$

This clearly shows that the magnetizing current is not in phase with the flux in leg 1.

By substituting (3) in (2) we similarly get

$$.4\pi n i_3 = (2R + R + P) Q_3 + \frac{R + R + P}{3} Q_2$$

which means the same thing as for magnetizing current i_1 . The flux in leg 1 though is lagging the current while that in leg e is leading.

When the transformer is fully loaded, viz. when the total current input is large compared to the magnetizing current the flux in each leg becomes more in phase with the magnetizing current.

In the case under consideration the load current input in the primary never was more than ten times the magnetizing current. Therefore the secondary voltages never were 120° apart.

To this add the effect of the impedances which produced another phase difference.

Hence the currents were not 120° apart and the fluxes induced in legs a and b were not the same.

1. The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation

$$f(x) = \int_0^x \frac{1}{1+t^2} dt, \quad (1)$$

where x is a real number. It is shown that the function $f(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$2. The second part of the paper is devoted to the study of the properties of the function $g(x)$ defined by the equation$$

$$g(x) = \int_0^x \frac{1}{1+t^4} dt, \quad (2)$$

where x is a real number. It is shown that the function $g(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$3. The third part of the paper is devoted to the study of the properties of the function $h(x)$ defined by the equation$$

$$h(x) = \int_0^x \frac{1}{1+t^6} dt, \quad (3)$$

where x is a real number. It is shown that the function $h(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$4. The fourth part of the paper is devoted to the study of the properties of the function $k(x)$ defined by the equation$$

$$k(x) = \int_0^x \frac{1}{1+t^8} dt, \quad (4)$$

where x is a real number. It is shown that the function $k(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$5. The fifth part of the paper is devoted to the study of the properties of the function $l(x)$ defined by the equation$$

$$l(x) = \int_0^x \frac{1}{1+t^{10}} dt, \quad (5)$$

where x is a real number. It is shown that the function $l(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$6. The sixth part of the paper is devoted to the study of the properties of the function $m(x)$ defined by the equation$$

$$m(x) = \int_0^x \frac{1}{1+t^{12}} dt, \quad (6)$$

where x is a real number. It is shown that the function $m(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$7. The seventh part of the paper is devoted to the study of the properties of the function $n(x)$ defined by the equation$$

$$n(x) = \int_0^x \frac{1}{1+t^{14}} dt, \quad (7)$$

where x is a real number. It is shown that the function $n(x)$ is increasing and concave down on the interval $(-\infty, \infty)$.

$$8. The eighth part of the paper is devoted to the study of the properties of the function $o(x)$ defined by the equation$$

Procedure to obtain results from the oscillographic readings:

The oscillograph gave the height of the maximum voltage. The effective value was then computed. The resistance of the oscillographic element and the outside resistance in series with it was measured. From the voltage applied on the oscillograph and the resistance of the element and the rheostat in series with it the current flowing in the oscillograph and the exploring coil was computed.

The impedance of the coil was next measured. Its direct current resistance was taken. From these two values the reactance of the coil was computed.

The drop in voltage in the oscillographic circuit is ohmic. To the value of the voltage across the oscillograph was directly added the ir drop in the coil and vectorially the ix drop. The total voltage gave the induced voltage in the coil.

Knowing the induced voltage and referring back to the formula for the induced voltage in a transformer the maximum flux was found. Knowing the cross sectional area of the legs the maximum flux density was computed and thence the hysteresis and eddy losses.

To get the average losses the average flux was used.

It is to be noticed that losses-distance curves were plotted for one set of readings. The areas under these curves were measured by a planimeter and the average loss taken. This checked very closely with the results of average losses found by using the average flux.

Formulae used on computation:

a. The impedance of the coil is found by

$$Z = \frac{E}{I}$$

where Z is impedance in ohms
 E the effective voltage (alternating current)
 I the effective current (" ")

The direct current resistance is

$$R = \frac{E}{I}$$

where R is resistance in ohms
 E direct current voltage in volts
 I direct current in amperes

The reactance of the coil is then

$$X = \sqrt{Z^2 - R^2} \quad \text{ohms.}$$

(Many readings for E_{alt} , I_{alt} , E_{dir} , and I_{dir} were taken. The average values of Z and R were taken to compute X .)

- b. The resistance of the element was found by applying direct current and taking readings of current and voltage.

$$R_0 = \frac{E}{I}$$

- c. The distance measured on the oscillograph is twice the maximum value. Half of that distance gives the maximum value. The effective voltage is

$$E_{eff} = .707 E_m$$

where E_m denotes the maximum value.

The total induced voltage is

$$E_t = \sqrt{(e + ir)^2 + (ix)^2}$$

where e is the load voltage in phase with current
 i the current flowing in the circuit
 i_r the drop across the ohmic resistance of the coil
 r the ohmic resistance of coil
 i_x drop across inductance of coil
 x reactance of coil.

d. The maximum can be calculated by the following formula

$$E_{\text{eff}} = 4.44 N f Q_m 10^{-8} \text{ volts}$$

Therefore
$$Q_m = \frac{E \times 10^8}{4.44 N f} \text{ lines}$$

where Q_m is maximum flux
 E the effective induced voltage
 N number of turns in coil
 f frequency in cycles per second.

The flux density is found thus

$$B_m = \frac{Q_m}{A}$$

where A is area of cross section in square centimeters

e. The hysteresis loss is computed by means of Steinmetz' empirical formula

$$P_h = K_h f B_m^{1.6} 10^{-7} \text{ watts per square centimeter}$$

where K_h is coefficient of hysteresis

f. The eddy loss is found thus

$$P_e = \frac{\pi^2}{6 P} h^2 f^2 B_m^2 10^{-16} \text{ watts per square centimeter}$$

where P is resistivity the material

h thickness of the sheet

g. The total losses are the sum of the hysteresis and eddy current losses

$$P_t = P_h + P_e$$

Results and Computation:

a. Resistance and impedance of coil

At 60 cycle frequency the impedance of the exploring coil was found to be

$$Z = 7.556 \text{ ohms}$$

Its direct current resistance was

$$R = 7.22 \text{ ohms}$$

Its reactance is then

$$\begin{aligned} X &= \sqrt{(7.556)^2 - (7.22)^2} \\ &= 2.24 \text{ ohms} \end{aligned}$$

b. Resistance of the element and outside rheostat in series.

This was found to be

$$R = 9.5$$

c. Applied load voltage.

The voltage applied from the coil on the oscillograph gave a deflection of $3/8"$ (1st set of readings on leg a with 360 amp.) With a direct current voltage of 2 volts the deflection was $9/8"$. The maximum value of voltage was then

$$E_m = \frac{2 \times 8 \times 3}{9 \times 8 \times 2} = .333$$

Its effective value was then

$$\begin{aligned} E_{\text{eff}} &= .707 \times .333 \\ &= .235 \text{ volts} \end{aligned}$$

The current flowing in the oscillograph and the coil was therefore

$$\begin{aligned} I &= \frac{.235}{9.5} \\ &= .0248 \text{ amp.} \end{aligned}$$

The i_r drop in the resistance of the coil was

$$\begin{aligned} i_r &= .0248 \times 7.22 \\ &= .179 \text{ volts} \end{aligned}$$

The i_x drop was

$$\begin{aligned} i_x &= .0248 \times 2.24 \\ &= .0556 \end{aligned}$$

The total induced voltage was

$$\begin{aligned} E_t &= \sqrt{(.235 + .179)^2 + (.0556)^2} \\ &= \sqrt{.171396 + .003091} \\ &= \sqrt{.174487} \\ &= .417 \end{aligned}$$

d. Flux

The maximum flux was therefore

$$\begin{aligned} Q_m &= \frac{.417 \times 10^8}{4.44 \times 60 \times 100} \\ &= 1565 \text{ lines} \end{aligned}$$

The area of the cross section being $3/8$ " or 2.418 sq. cm., the maximum flux density was

$$\begin{aligned} B_m &= \frac{1565}{2.418} \\ &= 648 \text{ lines per square centimeter} \end{aligned}$$

e. Hysteresis losses

The coefficient of hysteresis for that sample of steel is

$$K_h = .015$$

The hysteresis loss was therefore

$$\begin{aligned} P_h &= .015 \times 60 \times 648^{1.6} \times 10^{-7} \text{ watts per sq. cm.} \\ &= 28.36 \times 10^{-4} \text{ watts per sq. cm.} \end{aligned}$$

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f. The eddy current loss

The resistivity of steel at ordinary temperature is

$$P = 19 \text{ microhm centimeter}$$

The eddy current coefficient is therefore

$$\begin{aligned} K_e &= \frac{(3.14)^2 \times 10^6}{6 \times 19} \times (.315)^2 \\ &= 8.61 \times 10^3 \end{aligned}$$

.315 is the thickness of the steel in centimeter being $1/8$ of an inch.

The eddy current loss is therefore

$$\begin{aligned} P_e &= 8.61 \times 10^3 \times (60)^2 \times (648)^2 \times 10^{-16} \\ &= 13.0 \times 10^{-4} \text{ watts per sq. cm.} \end{aligned}$$

g. The total loss per square centimeter is

$$\begin{aligned} P_t &= (28.36 + 13) 10^{-4} \\ &= 41.36 \times 10^{-4} \text{ watts per sq. cm.} \end{aligned}$$

Measurement of the Impedance of Coil

Frequency 60 cycle. Direct Current

| I | E | Z ohm | I | V | R ohm |
|----------|------|-------|------|------|-------|
| .58 | 7.57 | 7.57 | .4 | 2.92 | 7.3 |
| .63 | 4.75 | 7.54 | .66 | 4.8 | 7.27 |
| .69 | 5.22 | 7.56 | .5 | 3.6 | 7.2 |
| .8 | 6.05 | 7.56 | .3 | 2.15 | 7.16 |
| .88 | 6.65 | 7.55 | .23 | 1.65 | 7.17 |
| Average | | 7.556 | 7.22 | | |
| x = 2.24 | | | | | |

Resistance of element and resistance

| I | V | R ohm |
|---------|------|-------|
| .1 | .95 | 9.5 |
| .2 | 1.94 | 9.7 |
| .31 | 2.9 | 9.35 |
| .396 | 3.75 | 9.46 |
| .5 | 4.73 | 9.46 |
| Average | | 9.5 |

Direct Current Resistance of Coil

| V | A | Res Coil | Average | |
|------|------|----------|---------|------|
| 2.92 | .4 | 7.3) | Coil | 7.22 |
| | |) | | |
| 4.8 | .66 | 7.27) | | |
| | |) | | |
| 3.6 | .5 | 7.2) | | |
| | |) | | |
| 2.15 | .3 | 7.16) | | |
| | |) | | |
| 1.65 | .23 | 7.17) | | |
| | |) | | |
| .95 | .1 | 9.5) | Set | 9.5 |
| | |) | | |
| 1.94 | .2 | 9.7) | | |
| | |) | | |
| 2.9 | .31 | 9.35) | | |
| | |) | | |
| 3.75 | .396 | 9.46) | | |
| | |) | | |
| 4.73 | .5 | 9.46) | | |

DATA

| | | | a | | | b | | | c | | |
|-------|-------|-------|-----|-------|-------|-----|-------|-----|------|-----|-----|
| I_a | I_b | I_c | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 360 | 360 | 360 | 3/8 | 11/16 | 13/16 | 3/4 | 13/16 | 1/2 | 5/16 | 3/8 | 1/4 |

$$L = 19.5$$

$$f = 60$$

Res on 9

| | | | | | | | | | | | |
|-----|-----|-----|------|------|-------|------|-----|------|-----|------|------|
| 310 | 310 | 310 | 5/16 | 9/16 | 11/16 | 9/16 | 5/8 | 7/16 | 1/4 | 5/16 | 3/16 |
|-----|-----|-----|------|------|-------|------|-----|------|-----|------|------|

Res on 9

$$f = 60$$

| | | | | | | | | | | | |
|-----|-----|-----|-----|------|------|-----|-----|------|------|-----|------|
| 230 | 230 | 230 | 1/4 | 7/16 | 8/16 | 1/2 | 1/2 | 5/16 | 3/16 | 1/4 | 3/16 |
|-----|-----|-----|-----|------|------|-----|-----|------|------|-----|------|

Res on 9

$$f = 60$$

| | | | | | | | | | | | |
|-----|-----|-----|------|-------|---|-------|---|-----|------|------|-----|
| 440 | 440 | 440 | 7/16 | 13/16 | 1 | 19/16 | 1 | 1/2 | 5/16 | 7/16 | 1/4 |
|-----|-----|-----|------|-------|---|-------|---|-----|------|------|-----|

Res on 9

$$f = 60$$

Phase Angle

$$a - b = 60^\circ$$

$$a - c = 30^\circ$$

It was noticed that there was a phase difference in the fluxes at different points on c, which amounts to around 60° between 1 and 2, 2 and 3. There was a very little angle between 2 and 3 on a and 1 and 3 on b, but no angle between 1 and 2 on a and 2 and 3 on b.

DATA

| a | | b | | c | | I _a | I _b | I _c | |
|------|------|-------|------|------|------|----------------|----------------|----------------|--------|
| max. | eff. | max. | eff. | max. | eff. | | | | |
| .333 | .235 | .666 | .470 | .277 | .195 | | | | |
| .611 | .431 | .722 | .510 | .333 | .235 | 360 | 360 | 360 | f = 60 |
| .722 | .510 | .444 | .314 | .222 | .157 | | | | |
| .277 | .195 | .527 | .372 | .222 | .157 | | | | |
| .500 | .353 | .555 | .392 | .277 | .195 | 310 | 310 | 310 | f = 60 |
| .611 | .431 | .388 | .274 | .166 | .117 | | | | |
| .222 | .157 | .444 | .314 | .166 | .117 | | | | |
| .388 | .274 | .444 | .314 | .222 | .157 | 230 | 230 | 230 | f = 60 |
| .472 | .333 | .277 | .195 | .166 | .117 | | | | |
| .388 | .274 | 1.054 | .744 | .277 | .195 | | | | |
| .722 | .510 | .888 | .628 | .388 | .274 | 440 | 440 | 440 | f = 60 |
| .888 | .628 | .444 | .314 | .222 | .157 | | | | |

DATA

| | | | | a | $(e')^2$ | | | | |
|------|-------|------|--------|-------|----------|------------|---------------|-------|-------|
| e | I | Ir | (e+Ir) | IX | $(IX)^2$ | $(e+Ir)^2$ | $e'^2 + IX^2$ | e_t | e_m |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .431 | .0454 | .327 | .758 | .101 | .010010 | .574564 | .584574 | .764 | 2870 |
| .510 | .0537 | .388 | .898 | .120 | .014400 | .806404 | .820804 | .906 | 3410 |
| | | | | | | | | | |
| .195 | .0205 | .148 | .343 | .0459 | .002106 | .117649 | .119756 | .346 | 1300 |
| .353 | .0372 | .268 | .621 | .0834 | .006955 | .385641 | .392597 | .626 | 2355 |
| .431 | .0454 | .327 | .758 | .101 | .010010 | .574564 | .584574 | .764 | 2870 |
| | | | | | | | | | |
| .157 | .0165 | .119 | .276 | .0369 | .0013616 | .076176 | .077538 | .278 | 1045 |
| .274 | .0288 | .208 | .482 | .0627 | .0039312 | .232324 | .236255 | .486 | 1825 |
| .333 | .0351 | .253 | .586 | .0787 | .0061436 | .343396 | .349590 | .591 | 2220 |
| | | | | | | | | | |
| .274 | .0288 | .208 | .482 | .0645 | .0041602 | .232324 | .236484 | .486 | 1825 |
| .510 | .0537 | .388 | .898 | .120 | .014400 | .806404 | .820804 | .906 | 3410 |
| .628 | .0661 | .477 | 1.105 | .148 | .021904 | 1.221025 | 1.242929 | 1.114 | 4190 |

$$I = \frac{e}{r_0} \quad \begin{array}{l} e = \text{e.m.f. recorded by oscillograph} \\ r_0 = \text{resistance of element and outside resistance} = 9.5 \end{array}$$

$$\text{Total } e = \sqrt{(e+ir)^2 + (ix)^2}$$

$$r = 7.22$$

$$x = 2.24$$

DATA

a

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $B_m^{1.6}$ | $10^{-4} w$
hys. loss | B_m^2 | Edd.L. | Total Losses
$w^{-4} w$ |
|----------|-------|------------|----------------|-------------|--------------------------|---------|--------|----------------------------|
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41386 |
| 2870 | 1190 | 3.07555 | 4.92088 | 83347 | 75.01 | 1416100 | 43.9 | 118.91 |
| 3410 | 1410 | 3.14922 | 5.038752 | 109450 | 98.50 | 1988100 | 61.6 | 160.10 |
| Av. | 1080 | 3.03743 | 4.859888 | 72450 | 65.20 | 1166400 | 36.2 | 101.4 |
| 1500 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.99 | 30.05 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| 2870 | 1190 | 3.07555 | 4.92088 | 83347 | 75.01 | 1416100 | 43.9 | 118.91 |
| Av. | 901 | 2.95472 | 4.72755 | 53400 | 48.06 | 811801 | 25.05 | 73.11 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 2220 | 920 | 2.96379 | 4.742064 | 55254 | 49.72 | 846400 | 26.25 | 75.97 |
| Av. | 702 | 2.84634 | 4.554144 | 35850 | 32.26 | 492804 | 15.3 | 47.56 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 3410 | 1410 | 3.14922 | 5.038752 | 109450 | 98.50 | 1988100 | 61.6 | 160.10 |
| 4190 | 1740 | 3.24055 | 5.18588 | 153060 | 136.75 | 3027600 | 93.9 | 230.65 |
| Av. | 1300 | 3.11394 | 4.982324 | 96020 | 86.41 | 1690000 | 52.4 | 136.81 |

DATA

b

| e | I | I_r | e'
$I_r + e$ | I_x | $\frac{2}{IX}$ | $(e')^2$ | $e'^2 + \frac{2}{IX}$ | E | ϕ_m |
|------|-------|-------|-------------------|-------|----------------|----------|-----------------------|-------|----------|
| .470 | .0495 | .357 | .827 | .111 | .012321 | .683929 | .696250 | .834 | 3350 |
| .510 | .0537 | .388 | .898 | .120 | .014400 | .806404 | .820804 | .906 | 3410 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .806404 | .820804 | .558 | 2100 |
| .372 | .0392 | .283 | .655 | .0879 | .007726 | .429025 | .436751 | .660 | 2480 |
| .392 | .0412 | .298 | .690 | .0924 | .008537 | .476100 | .484637 | .696 | 2618 |
| .274 | .0288 | .208 | .482 | .0646 | .004173 | .232324 | .236497 | .486 | 1825 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .305809 | .311315 | .558 | 2100 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .305809 | .311315 | .558 | 2100 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .744 | .0784 | .565 | 1.309 | .175 | .030625 | 1.713481 | 1.744106 | 1.320 | 4960 |
| .628 | .0661 | .477 | 1.105 | .148 | .021904 | 1.221025 | 1.242929 | 1.114 | 4190 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .305809 | .311315 | .558 | 2100 |

DATA

b

| ϕ_m | R_m | $\log R_m$ | $1.6 \log R_m$ | R_m | $10^{-4} w$
hys.Loss | R_m^2 | Ed.L.
$10^{-4} w$ | Total Losses
$w^{-4} w$ |
|----------|-------|------------|----------------|--------|-------------------------|---------|----------------------|----------------------------|
| 3350 | 1390 | 3.14301 | 5.028816 | 106875 | 96.16 | 1932100 | 59.9 | 156.06 |
| 3410 | 1410 | 3.14922 | 5.038752 | 109450 | 98.50 | 1416100 | 43.9 | 142.40 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| Av. | 1233 | 3.0910 | 4.9456 | 88200 | 79.38 | 1519289 | 47.2 | 126.58 |
| 2480 | 1050 | 3.01284 | 4.820544 | 66152 | 59.53 | 1060900 | 32.9 | 92.43 |
| 2620 | 1080 | 3.03342 | 4.853472 | 71364 | 64.22 | 1166400 | 36.2 | 100.42 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| Av. | 955 | 2.9800 | 4.768 | 58600 | 52.74 | 912025 | 28.22 | 80.96 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| Av. | 759 | 2.8802 | 4.60832 | 40600 | 36.54 | 576081 | 17.87 | 54.41 |
| 4960 | 2060 | 3.31387 | 5.302192 | 200530 | 180.47 | 4243600 | 131.5 | 311.97 |
| 4190 | 1740 | 3.24055 | 5.18488 | 153060 | 137.75 | 3027600 | 94.7 | 232.45 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| Av. | 1556 | 2.1920 | 5.1072 | 128000 | 115.2 | 2420000 | 75.0 | 190.20 |

DATA

c

| \bullet | I | IR | $\frac{e'}{IR+e}$ | IX | $(IX)^2$ | $(\frac{e'}{IR+e})^2$ | E^2 | Induced
E | $\frac{c}{m}$ |
|-----------|-------|------|-------------------|-------|----------|-----------------------|---------|--------------|---------------|
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .274 | .0288 | .208 | .482 | .0645 | .004160 | .232324 | .236484 | .486 | 1825 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |

DATA

c

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | B_m | $1.6 \cdot 10^{-4} w$
hys. Loss | B_m^2 | Ed.L.
10^{-4} | Total
10^{-4} Losses |
|----------|-------|------------|----------------|-------|------------------------------------|---------|--------------------|---------------------------|
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.30 |
| Av. | 539 | 2.7316 | 4.37065 | 23450 | 21.10 | 290521 | 9.02 | 30.12 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 775 | 320 | 2.50515 | 4.00824 | 10192 | 9.17 | 102400 | 3.82 | 12.99 |
| Av. | 430 | 2.6335 | 4.2136 | 16353 | 14.71 | 184900 | 5.74 | 20.45 |
| 775 | 320 | 2.50515 | 4.00824 | 10192 | 9.17 | 102400 | 3.82 | 12.99 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 775 | 320 | 2.50515 | 4.00824 | 10192 | 9.17 | 102400 | 3.82 | 12.99 |
| Av. | 357 | 2.5527 | 4.08432 | 12142 | 10.92 | 127449 | 3.96 | 14.88 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| Av. | 575 | 2.7597 | 4.41552 | 26030 | 23.42 | 330625 | 10.22 | 33.64 |

DATA

Summary of Results

$$L = 19.5'$$

| a | | | b | | | b | | | $I_a=360$
$I_b=371$
$I_c=360$ |
|----------------------|------------|------------|------------|------------|--------------|------------|------------|------------|-------------------------------------|
| W_h | W_c | Total | W_h | W_c | Total | W_h | W_c | Total | |
| 10^{-4w} | 10^{-4w} | 10^{-4w} | 10^{-4w} | 10^{-4w} | 10^{-4w} | 10^{-4w} | 10^{-4w} | 10^{-4w} | |
| 28.36 | 13.0 | 41.36 | 96.16 | 59.9 | 156.06 | 21.06 | 8.97 | 30.03 | |
| 75.01 | 43.9 | 118.91 | 98.50 | 43.9 | 142.40 | 28.36 | 13.00 | 41.36 | |
| 98.50 | 61.6 | 160.10 | 45.44 | 23.5 | 68.94 | 14.88 | 5.82 | 20.70 | |
| 65.20 | 36.2 | 101.4 | 79.38 | 47.2 | 126.58 | 21.10 | 9.02 | 30.12 | Av. |
| Average losses per) | | | Hys. | 55.23 | | | | | |
| cu. cen. of tower) | | | Edd. | 30.81 | Total | 86.04 | | | |
| 21.06 | 8.99 | 30.05 | 59.53 | 32.9 | 92.43 | 14.88 | 5.82 | 20.70 | $I_a=310$ |
| 54.53 | 29.5 | 84.03 | 64.22 | 36.2 | 100.42 | 21.06 | 8.97 | 30.03 | $I_b=321$ |
| 75.01 | 43.9 | 118.91 | 36.22 | 17.7 | 53.92 | 9.17 | 3.82 | 12.99 | $I_c=303$ |
| 48.06 | 25.05 | 73.11 | 52.74 | 28.22 | 80.96 | 14.71 | 5.74 | 20.45 | Av. |
| Hys. 38.50 | | | Edd. 19.67 | | Total 58.17 | | | | |
| 14.88 | 5.82 | 20.7 | 45.44 | 23.5 | 68.94 | 9.17 | 3.82 | 12.99 | $I_a=235$ |
| 36.22 | 17.7 | 53.92 | 45.44 | 23.5 | 68.94 | 14.88 | 5.82 | 20.70 | $I_b=240$ |
| 49.72 | 26.25 | 75.97 | 21.06 | 8.97 | 30.03 | 9.17 | 3.82 | 12.99 | $I_c=228$ |
| 32.26 | 15.3 | 47.56 | 36.54 | 17.87 | 54.41 | 10.92 | 3.96 | 14.88 | Av. |
| Hys. 26.57 | | | Edd. 12.38 | | Total 38.95 | | | | |
| 36.22 | 17.7 | 53.92 | 180.47 | 131.5 | 311.97 | 21.06 | 8.97 | 30.03 | $I_a=440$ |
| 98.50 | 61.7 | 160.10 | 137.75 | 94.7 | 232.45 | 36.22 | 17.7 | 53.92 | $I_b=430$ |
| 136.75 | 93.9 | 230.65 | 45.44 | 23.5 | 68.94 | 14.88 | 5.82 | 20.70 | $I_c=440$ |
| 86.41 | 52.4 | 136.81 | 115.2 | 75.0 | 190.2 | 23.42 | 10.22 | 33.64 | Av. |
| Hys. 75.01 | | | Edd. 45.87 | | Total 120.88 | | | | |

Mathematics

Algebra

Equations

| | | | | |
|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| 1. Solve for x: $2x + 5 = 15$ | 2. Solve for x: $3x - 7 = 8$ | 3. Solve for x: $4x + 1 = 10$ | 4. Solve for x: $5x - 2 = 18$ | 5. Solve for x: $6x + 3 = 21$ |
| 6. Solve for x: $7x - 4 = 25$ | 7. Solve for x: $8x + 1 = 30$ | 8. Solve for x: $9x - 5 = 38$ | 9. Solve for x: $10x + 2 = 42$ | 10. Solve for x: $11x - 3 = 50$ |
| 11. Solve for x: $12x + 4 = 60$ | 12. Solve for x: $13x - 6 = 68$ | 13. Solve for x: $14x + 1 = 77$ | 14. Solve for x: $15x - 4 = 86$ | 15. Solve for x: $16x + 5 = 95$ |
| 16. Solve for x: $17x - 7 = 104$ | 17. Solve for x: $18x + 2 = 113$ | 18. Solve for x: $19x - 9 = 122$ | 19. Solve for x: $20x + 3 = 131$ | 20. Solve for x: $21x - 5 = 140$ |

Geometry

Area

| | | | | |
|---|---|---|---|---|
| 1. Find the area of a rectangle with length 5 and width 3. | 2. Find the area of a rectangle with length 7 and width 4. | 3. Find the area of a rectangle with length 9 and width 5. | 4. Find the area of a rectangle with length 11 and width 6. | 5. Find the area of a rectangle with length 13 and width 7. |
| 6. Find the area of a rectangle with length 15 and width 8. | 7. Find the area of a rectangle with length 17 and width 9. | 8. Find the area of a rectangle with length 19 and width 10. | 9. Find the area of a rectangle with length 21 and width 11. | 10. Find the area of a rectangle with length 23 and width 12. |
| 11. Find the area of a rectangle with length 25 and width 13. | 12. Find the area of a rectangle with length 27 and width 14. | 13. Find the area of a rectangle with length 29 and width 15. | 14. Find the area of a rectangle with length 31 and width 16. | 15. Find the area of a rectangle with length 33 and width 17. |
| 16. Find the area of a rectangle with length 35 and width 18. | 17. Find the area of a rectangle with length 37 and width 19. | 18. Find the area of a rectangle with length 39 and width 20. | 19. Find the area of a rectangle with length 41 and width 21. | 20. Find the area of a rectangle with length 43 and width 22. |

Calculus

Derivatives

| | | | | |
|--|---|---|--|--|
| 1. Find the derivative of $f(x) = x^2 + 3x - 5$. | 2. Find the derivative of $f(x) = 2x^3 - 4x^2 + 7x - 1$. | 3. Find the derivative of $f(x) = x^4 - 2x^3 + 5x^2 - 3x + 1$. | 4. Find the derivative of $f(x) = 3x^5 - 7x^4 + 11x^3 - 9x^2 + 2x - 6$. | 5. Find the derivative of $f(x) = x^6 - 4x^5 + 8x^4 - 12x^3 + 15x^2 - 10x + 3$. |
| 6. Find the derivative of $f(x) = 2x^7 - 5x^6 + 9x^5 - 13x^4 + 17x^3 - 21x^2 + 25x - 30$. | 7. Find the derivative of $f(x) = x^8 - 3x^7 + 6x^6 - 10x^5 + 14x^4 - 18x^3 + 22x^2 - 26x + 30$. | 8. Find the derivative of $f(x) = 4x^9 - 7x^8 + 11x^7 - 15x^6 + 19x^5 - 23x^4 + 27x^3 - 31x^2 + 35x - 39$. | 9. Find the derivative of $f(x) = 5x^{10} - 8x^9 + 12x^8 - 16x^7 + 20x^6 - 24x^5 + 28x^4 - 32x^3 + 36x^2 - 40x + 44$. | 10. Find the derivative of $f(x) = 6x^{11} - 9x^{10} + 13x^9 - 17x^8 + 21x^7 - 25x^6 + 29x^5 - 33x^4 + 37x^3 - 41x^2 + 45x - 49$. |

Statistics

Mean

| | | | | |
|---|---|--|--|---|
| 1. Find the mean of the numbers 2, 4, 6, 8, 10. | 2. Find the mean of the numbers 3, 5, 7, 9, 11. | 3. Find the mean of the numbers 4, 6, 8, 10, 12. | 4. Find the mean of the numbers 5, 7, 9, 11, 13. | 5. Find the mean of the numbers 6, 8, 10, 12, 14. |
|---|---|--|--|---|

DATA

| | | | a | | | | b | | | | c | | | |
|----------------|----------------|----------------|------|-----|-------|-----|-----|-----|-------|-----|------|------|-----|-----|
| I _a | I _b | I _c | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 470 | 475 | 475 | 5/16 | 1/2 | 13/16 | 7/8 | 7/8 | 7/8 | 11/16 | 3/8 | 7/32 | 7/16 | 3/8 | 1/4 |

$$B - C = 180$$

$$L = 24''$$

$$f = \frac{1200 \times 60}{1200} = 60$$

$$R = 9$$

365 363 365 7/32 3/8 9/16 11/16 11/16 9/16 5/16 3/16 5/16 5/16 3/16

$$f = 60 \quad S = 1200$$

315 320 310 3/16 5/16 1/2 9/16 9/16 19/32 1/2 9/32 5/32 9/32 7/32 5/32

$$S = 1200$$

DATA

| a | | b | | c | | I _a | I _b | I _c | |
|------|------|------|------|------|------|----------------|----------------|----------------|---------|
| max. | eff. | max. | eff. | max. | eff. | | | | |
| .277 | .195 | .776 | .548 | .194 | .137 | | | | |
| .444 | .314 | .776 | .548 | .388 | .274 | 470 | 475 | 475 | f = 60 |
| .722 | .510 | .611 | .431 | .333 | .235 | | | | L = 24" |
| .776 | .548 | .333 | .235 | .222 | .157 | | | | |
| .194 | .137 | .611 | .431 | .166 | .117 | | | | |
| .333 | .235 | .611 | .431 | .277 | .195 | 365 | 363 | 365 | f = 60 |
| .537 | .372 | .500 | .353 | .277 | .195 | | | | |
| .611 | .431 | .277 | .195 | .166 | .117 | | | | |
| .166 | .117 | .500 | .353 | .138 | .097 | | | | |
| .277 | .195 | .527 | .372 | .500 | .353 | 315 | 320 | 310 | f = 60 |
| .444 | .314 | .444 | .314 | .194 | .137 | | | | |
| .500 | .353 | .250 | .177 | .138 | .097 | | | | |

DATA

| \bullet | I | IR | $\frac{e^*}{e+IR}$ | $\frac{a}{IX}$ | $(IX)^2$ | $(e^*)^2$ | Induced
E^2 | E | \bullet_m |
|-----------|-------|------|--------------------|----------------|----------|-----------|------------------|------|-------------|
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .314 | .0331 | .239 | .553 | .0741 | .005506 | .305809 | .311315 | .558 | 2100 |
| .510 | .0537 | .388 | .898 | .120 | .014400 | .806404 | .820804 | .906 | 3410 |
| .548 | .0577 | .417 | .965 | .1291 | .016641 | .931225 | .947866 | .973 | 3660 |
| .137 | .0144 | .104 | .241 | .0323 | .001043 | .058081 | .059124 | .243 | 915 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .372 | .0392 | .283 | .655 | .0879 | .007726 | .429025 | .436751 | .660 | 2480 |
| .431 | .0454 | .327 | .758 | .101 | .010010 | .574564 | .584574 | .764 | 2870 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .305809 | .311315 | .558 | 2100 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .388641 | .392597 | .626 | 2355 |

DATA

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $\frac{a}{B_m}$ | | B_m^2 | Total Losses | |
|----------|-------|------------|----------------|-----------------|-----------|---------|-------------------------|------------|
| | | | | 1.6 | 10^{-4} | | $\frac{Ed.L.}{10^{-4}}$ | $10^{-4}w$ |
| | | | | $Hys.L.$ | | | | |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| 3410 | 1410 | 3.14922 | 5.038752 | 109450 | 98.50 | 1988100 | 61.6 | 160.10 |
| 3660 | 1520 | 3.18184 | 5.090944 | 123230 | 110.90 | 2310400 | 71.6 | 182.50 |
| Av. | 1084 | 3.0350 | 4.8560 | 71800 | 64.62 | 1178000 | 36.5 | 101.12 |
| | | | | | | | | |
| 915 | 378 | 2.57749 | 4.123984 | 13305 | 11.97 | 142884 | 4.43 | 16.40 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| 2480 | 1030 | 3.01284 | 4.820544 | 66152 | 59.53 | 1060900 | 32.9 | 92.43 |
| 2870 | 1190 | 3.07555 | 4.92088 | 83347 | 75.01 | 1416100 | 43.9 | 118.91 |
| Av. | 811 | 2.9090 | 4.6544 | 45125 | 40.61 | 657721 | 20.4 | 61.01 |
| | | | | | | | | |
| 775 | 320 | 2.50515 | 4.00824 | 10192 | 9.17 | 102400 | 3.82 | 12.99 |
| 1200 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| Av. | 676 | 2.7604 | 4.41664 | 26100 | 23.49 | 456976 | 14.12 | 37.61 |

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. The text outlines various methods for organizing and storing data, including digital databases and physical filing systems.

2. The second section focuses on the role of communication in project management. It highlights the need for clear, concise, and timely communication between team members and stakeholders. The text provides guidelines for effective communication, such as using appropriate channels and formats, and encourages regular updates and feedback loops.

3. The third part of the document addresses the challenges of resource allocation and management. It discusses the importance of understanding the capabilities and limitations of available resources, and provides strategies for optimizing their use. The text also touches upon the need for flexibility and adaptability in response to changing circumstances.

4. The final section discusses the importance of risk management and contingency planning. It emphasizes the need to identify potential risks early on and develop strategies to mitigate them. The text provides a framework for assessing risks and developing contingency plans, and encourages a proactive approach to risk management.

5. The document also includes a detailed discussion on the importance of data security and privacy. It outlines best practices for protecting sensitive information, such as using encryption, access controls, and secure communication channels. The text also addresses the legal and ethical implications of data handling and storage.

6. In addition, the document provides a comprehensive overview of the various tools and technologies used in modern project management. It discusses the benefits and limitations of different software solutions, and provides recommendations for selecting the most appropriate tools for a given project.

7. The document concludes with a summary of the key points discussed and a call to action for the reader. It emphasizes the importance of continuous learning and improvement in project management, and encourages the reader to apply the principles and practices discussed in the document to their own work.

8. The document also includes a detailed discussion on the importance of stakeholder engagement and communication. It outlines strategies for identifying and engaging stakeholders, and provides guidelines for effective communication with them. The text emphasizes the need for transparency and honesty in all communications, and encourages the use of multiple channels and formats to reach different audiences.

9. In addition, the document provides a comprehensive overview of the various challenges and risks associated with project management. It discusses the importance of anticipating and addressing these challenges proactively, and provides strategies for managing them effectively. The text also touches upon the need for flexibility and adaptability in response to changing circumstances.

10. The document concludes with a final summary of the key points discussed and a call to action for the reader. It emphasizes the importance of continuous learning and improvement in project management, and encourages the reader to apply the principles and practices discussed in the document to their own work.

DATA

b

| e | I | IR | e'
IR+e | IX | (IX) ² | (e') ² | (L _t) ² | Induced
E | e _m |
|------|-------|------|------------|-------|-------------------|-------------------|--------------------------------|--------------|----------------|
| .548 | .0577 | .417 | .965 | .129 | .016641 | .931225 | .947866 | .973 | 3660 |
| .548 | .0577 | .417 | .965 | .129 | .016641 | .931225 | .947866 | .973 | 3660 |
| .431 | .0454 | .327 | .758 | .101 | .010010 | .574564 | .584574 | .764 | 2870 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .431 | .0248 | .178 | .609 | .0556 | .003091 | .370881 | .373972 | .611 | 2300 |
| .431 | .0248 | .178 | .609 | .0556 | .003091 | .370881 | .373972 | .611 | 2300 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .626 | 2355 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .626 | 2355 |
| .372 | .0392 | .283 | .655 | .0879 | .007726 | .429025 | .436751 | .660 | 2480 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .305809 | .311315 | .558 | 2100 |
| .177 | .0186 | .134 | .311 | .0417 | .001738 | .096721 | .098459 | .313 | 1175 |

DATA

b

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $1.6 B_m$ | 10^{-4}
Hys.L. | B_m^2 | Ed.L.
10^{-4} | Total Losses
10^{-4} |
|-------------|-------|------------|----------------|-----------|---------------------|---------|--------------------|---------------------------|
| 3660 | 1510 | 3.17898 | 5.090944 | 123230 | 110.90 | 2280100 | 71.6 | 182.50 |
| 3660 | 1510 | 3.17898 | 5.090944 | 123230 | 110.90 | 2280100 | 71.6 | 182.50 |
| 2870 | 1190 | 3.07555 | 4.92088 | 83347 | 75.01 | 1416100 | 43.9 | 118.91 |
| 1865 | 770 | 2.88649 | 4.518384 | 41532 | 37.37 | 592900 | 18.4 | 55.77 |
| $\Delta v.$ | 1245 | 3.0952 | 4.95232 | 89600 | 80.64 | 55000 | 48.1 | 128.74 |
| 2300 | 950 | 2.97772 | 4.764352 | 58123 | 52.31 | 902500 | 28.0 | 80.31 |
| 2300 | 950 | 2.97772 | 4.764352 | 58123 | 52.31 | 902500 | 28.0 | 80.31 |
| 2355 | 975 | 2.98800 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| $\Delta v.$ | 853 | 2.9309 | 4.68944 | 48910 | 44.01 | 727609 | 22.59 | 66.60 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| 2480 | 1020 | 3.01284 | 4.820544 | 66152 | 59.53 | 1060900 | 32.9 | 92.45 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| 1175 | 486 | 2.68664 | 4.298624 | 19888 | 17.89 | 236196 | 7.33 | 25.22 |
| $\Delta v.$ | 840 | 2.9243 | 4.67888 | 47730 | 42.95 | 705600 | 21.85 | 64.8 |

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185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 | 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 347 | 348 | 349 | 350 | 351 | 352 | 353 | 354 | 355 | 356 | 357 | 358 | 359 | 360 | 361 | 362 | 363 | 364 | 365 | 366 | 367 | 368 | 369 | 370 | 371 | 372 | 373 | 374 | 375 | 376 | 377 | 378 | 379 | 380 | 381 | 382 | 383 | 384 | 385 | 386 | 387 | 388 | 389 | 390 | 391 | 392 | 393 | 394 | 395 | 396 | 397 | 398 | 399 | 400 | 401 | 402 | 403 | 404 | 405 | 406 | 407 | 408 | 409 | 410 | 411 | 412 | 413 | 414 | 415 | 416 | 417 | 418 | 419 | 420 | 421 | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 | 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 | 457 | 458 | 459 | 460 | 461 | 462 | 463 | 464 | 465 | 466 | 467 | 468 | 469 | 470 | 471 | 472 | 473 | 474 | 475 | 476 | 477 | 478 | 479 | 480 | 481 | 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 | 492 | 493 | 494 | 495 | 496 | 497 | 498 | 499 | 500 | 501 | 502 | 503 | 504 | 505 | 506 | 507 | 508 | 509 | 510 | 511 | 512 | 513 | 514 | 515 | 516 | 517 | 518 | 519 | 520 | 521 | 522 | 523 | 524 | 525 | 526 | 527 | 528 | 529 | 530 | 531 | 532 | 533 | 534 | 535 | 536 | 537 | 538 | 539 | 540 | 541 | 542 | 543 | 544 | 545 | 546 | 547 | 548 | 549 | 550 | 551 | 552 | 553 | 554 | 555 | 556 | 557 | 558 | 559 | 560 | 561 | 562 | 563 | 564 | 565 | 566 | 567 | 568 | 569 | 570 | 571 | 572 | 573 | 574 | 575 | 576 | 577 | 578 | 579 | 580 | 581 | 582 | 583 | 584 | 585 | 586 | 587 | 588 | 589 | 590 | 591 | 592 | 593 | 594 | 595 | 596 | 597 | 598 | 599 | 600 | 601 | 602 | 603 | 604 | 605 | 606 | 607 | 608 | 609 | 610 | 611 | 612 | 613 | 614 | 615 | 616 | 617 | 618 | 619 | 620 | 621 | 622 | 623 | 624 | 625 | 626 | 627 | 628 | 629 | 630 | 631 | 632 | 633 | 634 | 635 | 636 | 637 | 638 | 639 | 640 | 641 | 642 | 643 | 644 | 645 | 646 | 647 | 648 | 649 | 650 | 651 | 652 | 653 | 654 | 655 | 656 | 657 | 658 | 659 | 660 | 661 | 662 | 663 | 664 | 665 | 666 | 667 | 668 | 669 | 670 | 671 | 672 | 673 | 674 | 675 | 676 | 677 | 678 | 679 | 680 | 681 | 682 | 683 | 684 | 685 | 686 | 687 | 688 | 689 | 690 | 691 | 692 | 693 | 694 | 695 | 696 | 697 | 698 | 699 | 700 | 701 | 702 | 703 | 704 | 705 | 706 | 707 | 708 | 709 | 710 | 711 | 712 | 713 | 714 | 715 | 716 | 717 | 718 | 719 | 720 | 721 | 722 | 723 | 724 | 725 | 726 | 727 | 728 | 729 | 730 | 731 | 732 | 733 | 734 | 735 | 736 | 737 | 738 | 739 | 740 | 741 | 742 | 743 | 744 | 745 | 746 | 747 | 748 | 749 | 750 | 751 | 752 | 753 | 754 | 755 | 756 | 757 | 758 | 759 | 760 | 761 | 762 | 763 | 764 | 765 | 766 | 767 | 768 | 769 | 770 | 771 | 772 | 773 | 774 | 775 | 776 | 777 | 778 | 779 | 780 | 781 | 782 | 783 | 784 | 785 | 786 | 787 | 788 | 789 | 790 | 791 | 792 | 793 | 794 | 795 | 796 | 797 | 798 | 799 | 800 | 801 | 802 | 803 | 804 | 805 | 806 | 807 | 808 | 809 | 810 | 811 | 812 | 813 | 814 | 815 | 816 | 817 | 818 | 819 | 820 | 821 | 822 | 823 | 824 | 825 | 826 | 827 | 828 | 829 | 830 | 831 | 832 | 833 | 834 | 835 | 836 | 837 | 838 | 839 | 840 | 841 | 842 | 843 | 844 | 845 | 846 | 847 | 848 | 849 | 850 | 851 | 852 | 853 | 854 | 855 | 856 | 857 | 858 | 859 | 860 | 861 | 862 | 863 | 864 | 865 | 866 | 867 | 868 | 869 | 870 | 871 | 872 | 873 | 874 | 875 | 876 | 877 | 878 | 879 | 880 | 881 | 882 | 883 | 884 | 885 | 886 | 887 | 888 | 889 | 890 | 891 | 892 | 893 | 894 | 895 | 896 | 897 | 898 | 899 | 900 | 901 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 909 | 910 | 911 | 912 | 913 | 914 | 915 | 916 | 917 | 918 | 919 | 920 | 921 | 922 | 923 | 924 | 925 | 926 | 927 | 928 | 929 | 930 | 931 | 932 | 933 | 934 | 935 | 936 | 937 | 938 | 939 | 940 | 941 | 942 | 943 | 944 | 945 | 946 | 947 | 948 | 949 | 950 | 951 | 952 | 953 | 954 | 955 | 956 | 957 | 958 | 959 | 960 | 961 | 962 | 963 | 964 | 965 | 966 | 967 | 968 | 969 | 970 | 971 | 972 | 973 | 974 | 975 | 976 | 977 | 978 | 979 | 980 | 981 | 982 | 983 | 984 | 985 | 986 | 987 | 988 | 989 | 990 | 991 | 992 | 993 | 994 | 995 | 996 | 997 | 998 | 999 | 1000 | 1001 | 1002 | 1003 | 1004 | 1005 | 1006 | 1007 | 1008 | 1009 | 1010 | 1011 | 1012 | 1013 | 1014 | 1015 | 1016 | 1017 | 1018 | 1019 | 1020 | 1021 | 1022 | 1023 | 1024 | 1025 | 1026 | 1027 | 1028 | 1029 | 1030 | 1031 | 1032 | 1033 | 1034 | 1035 | 1036 | 1037 | 1038 | 1039 | 1040 | 1041 | 1042 | 1043 | 1044 | 1045 | 1046 | 1047 | 1048 | 1049 | 1050 | 1051 | 1052 | 1053 | 1054 | 1055 | 1056 | 1057 | 1058 | 1059 | 1060 | 1061 | 1062 | 1063 | 1064 | 1065 | 1066 | 1067 | 1068 | 1069 | 1070 | 1071 | 1072 | 1073 | 1074 | 1075 | 1076 | 1077 | 1078 | 1079 | 1080 | 1081 | 1082 | 1083 | 1084 | 1085 | 1086 | 1087 | 1088 | 1089 | 1090 | 1091 | 1092 | 1093 | 1094 | 1095 | 1096 | 1097 | 1098 | 1099 | 1100 | 1101 | 1102 | 1103 | 1104 | 1105 | 1106 | 1107 | 1108 | 1109 | 1110 | 1111 | 1112 | 1113 | 1114 | 1115 | 1116 | 1117 | 1118 | 1119 | 1120 | 1121 | 1122 | 1123 | 1124 | 1125 | 1126 | 1127 | 1128 | 1129 | 1130 | 1131 | 1132 | 1133 | 1134 | 1135 | 1136 | 1137 | 1138 | 1139 | 1140 | 1141 | 1142 | 1143 | 1144 | 1145 | 1146 | 1147 | 1148 | 1149 | 1150 | 1151 | 1152 | 1153 | 1154 | 1155 | 1156 | 1157 | 1158 | 1159 | 1160 | 1161 | 1162 | 1163 | 1164 | 1165 | 1166 | 1167 | 1168 | 1169 | 1170 | 1171 | 1172 | 1173 | 1174 | 1175 | 1176 | 1177 | 1178 | 1179 | 1180 | 1181 | 1182 | 1183 | 1184 | 1185 | 1186 | 1187 | 1188 | 1189 | 1190 | 1191 | 1192 | 1193 | 1194 | 1195 | 1196 | 1197 | 1198 | 1199 | 1200 | 1201 | 1202 | 1203 | 1204 | 1205 | 1206 | 1207 | 1208 | 1209 | 1210 | 1211 | 1212 | 1213 | 1214 | 1215 | 1216 | 1217 | 1218 | 1219 | 1220 | 1221 | 1222 | 1223 | 1224 | 1225 | 1226 | 1227 | 1228 | 1229 | 1230 | 1231 | 1232 | 1233 | 1234 | 1235 | 1236 | 1237 | 1238 | 1239 | 1240 | 1241 | 1242 | 1243 | 1244 | 1245 | 1246 | 1247 | 1248 | 1249 | 1250 | 1251 | 1252 | 1253 | 1254 | 1255 | 1256 | 1257 | 1258 | 1259 | 1260 | 1261 | 1262 | 1263 | 1264 | 1265 | 1266 | 1267 | 1268 | 1269 | 1270 | 1271 | 1272 | 1273 | 1274 | 1275 | 1276 | 1277 | 1278 | 1279 | 1280 | 1281 | 1282 | 1283 | 1284 | 1285 | 1286 | 1287 | 1288 | 1289 | 1290 | 1291 | 1292 | 1293 | 1294 | 1295 | 1296 | 1297 | 1298 | 1299 | 1300 | 1301 | 1302 | 1303 | 1304 | 1305 | 1306 | 1307 | 1308 | 1309 | 1310 | 1311 | 1312 | 1313 | 1314 | 1315 | 1316 | 1317 | 1318 | 1319 | 1320 | 1321 | 1322 | 1323 | 1324 | 1325 | 1326 | 1327 | 1328 | 1329 | 1330 | 1331 | 1332 | 1333 | 1334 | 1335 | 1336 | 1337 | 1338 | 1339 | 1340 | 1341 | 1342 | 1343 | 1344 | 1345 | 1346 | 1347 | 1348 | 1349 | 1350 | 1351 | 1352 | 1353 | 1354 | 1355 | 1356 | 1357 | 1358 | 1359 | 1360 | 1361 | 1362 | 1363 | 1364 | 1365 | 1366 | 1367 | 1368 | 1369 | 1370 | 1371 | 1372 | 1373 | 1374 | 1375 | 1376 | 1377 | 1378 | 1379 | 1380 | 1381 | 1382 | 1383 | 1384 | 1385 | 1386 | 1387 | 1388 | 1389 | 1390 | 1391 | 1392 | 1393 | 1394 | 1395 | 1396 | 1397 | 1398 | 1399 | 1400 | 1401 | 1402 | 1403 | 1404 | 1405 | 1406 | 1407 | 1408 | 1409 | 1410 | 1411 | 1412 | 1413 | 1414 | 1415 | 1416 | 1417 | 1418 | 1419 | 1420 | 1421 | 1422 | 1423 | 1424 | 1425 | 1426 | 1427 | 1428 | 1429 | 1430 | 1431 | 1432 | 1433 | 1434 | 1435 | 1436 | 1437 | 1438 | 1439 | 1440 | 1441 | 1442 | 1443 | 1444 | 1445 | 1446 | 1447 | 1448 | 1449 | 1450 | 1451 | 1452 | 1453 | 1454 | 1455 | 1456 | 1457 | 1458 | 1459 | 1460 | 1461 | 1462 | 1463 | 1464 | 1465 | 1466 | 1467 | 1468 | 1469 | 1470 | 1471 | 1472 | 1473 | 1474 | 1475 | 1476 | 1477 | 1478 | 1479 | 1480 | 1481 | 1482 | 1483 | 1484 | 1485 | 1486 |
|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|

DATA

| c | | | | | | | | | |
|------|-------|-------|-------------------|-------|----------|----------|--------------------|------|-------|
| e | I | IR | $\frac{e'}{IR+e}$ | IX | $(IX)^2$ | $(e')^2$ | Induced
$(E)^2$ | E | e_m |
| .137 | .0144 | .104 | .241 | .0323 | .001043 | .058081 | .059124 | .243 | 915 |
| .274 | .0288 | .208 | .482 | .0645 | .004160 | .232324 | .236484 | .486 | 1825 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .626 | 2355 |
| .137 | .0144 | .104 | .241 | .0323 | .001043 | .058081 | .059124 | .243 | 915 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |

DATA

c

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $1.6 B_m$ | 10^{-4}
Hys.L. | B_m^2 | 10^{-4}
Ed.L. | Total Losses
$10^{-4} w$ |
|----------|-------|------------|----------------|-----------|---------------------|---------|--------------------|-----------------------------|
| 915 | 379 | 2.57864 | 4.123984 | 13305 | 11.97 | 143641 | 4.43 | 16.40 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| Av. | 554 | 2.7435 | 4.3896 | 24525 | 22.07 | 306916 | 9.52 | 31.57 |
| 775 | 312 | 2.49415 | 4.00824 | 10192 | 9.17 | 97344 | 3.82 | 12.99 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 775 | 312 | 2.49415 | 4.00824 | 10192 | 9.17 | 97344 | 3.82 | 12.99 |
| Av. | 425 | 2.6284 | 4.20544 | 16046 | 14.44 | 180625 | 5.60 | 20.04 |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.46 | 83.99 |
| 915 | 379 | 2.57864 | 4.123984 | 13305 | 11.97 | 143641 | 4.43 | 16.40 |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| Av. | 473 | 2.6749 | 4.27984 | 19045 | 17.14 | 223729 | 6.94 | 24.08 |

DATA

Summary of Results

$$L = 24''$$

| a | | | b | | | c | | | |
|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-----------|
| W_h | W_c | Total | W_h | W_c | Total | W_h | W_c | Total | |
| $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | $10^{-4} w$ | |
| 21.06 | 8.97 | 30.03 | 110.90 | 71.6 | 182.50 | 11.97 | 4.43 | 16.40 | $I_a=470$ |
| 45.44 | 23.5 | 68.94 | 110.90 | 71.6 | 182.50 | 36.22 | 17.7 | 53.92 | $I_b=475$ |
| 98.50 | 61.6 | 160.10 | 75.01 | 43.9 | 118.91 | 28.36 | 13.0 | 41.36 | $I_c=475$ |
| 110.90 | 71.6 | 182.50 | 37.37 | 18.4 | 55.77 | 14.88 | 5.82 | 20.70 | |
| 64.62 | 36.5 | 101.12 | 80.64 | 48.1 | 128.74 | 22.07 | 9.52 | 31.57 | Av. |

| | | | | | | | | | |
|-------|-------|--------|-------|-------|-------|--|------|-------|-----------|
| Hys. | 49.78 | Edd. | 31.27 | Total | 81.15 | Average losses per
cu. cm. of tower | | | |
| 11.97 | 4.43 | 16.40 | 52.31 | 28.0 | 80.31 | 9.17 | 3.82 | 12.99 | $I_a=360$ |
| 28.36 | 13.0 | 41.36 | 52.31 | 28.0 | 80.31 | 21.06 | 8.97 | 30.03 | $I_b=363$ |
| 59.53 | 32.9 | 92.43 | 54.53 | 29.5 | 84.03 | 21.06 | 8.97 | 30.03 | $I_c=360$ |
| 75.01 | 43.9 | 118.91 | 21.06 | 8.97 | 30.03 | 9.17 | 3.82 | 12.99 | |
| 40.61 | 20.4 | 61.01 | 44.01 | 22.59 | 66.6 | 14.44 | 5.60 | 20.04 | Av. |

| | | | | | | | | | |
|-------|-------|-------|-------|-------|-------|--|-------|-------|-----------|
| Hys. | 33.02 | Edd. | 16.20 | Total | 49.22 | Average losses per
cu. cm. of tower | | | |
| 9.17 | 3.82 | 12.99 | 54.53 | 29.5 | 84.03 | 6.94 | 2.24 | 9.18 | $I_a=322$ |
| 21.06 | 8.97 | 30.03 | 59.53 | 32.9 | 92.43 | 54.53 | 29.46 | 83.99 | $I_b=322$ |
| 45.44 | 23.5 | 68.94 | 45.44 | 23.5 | 68.94 | 11.97 | 4.43 | 16.40 | $I_c=322$ |
| 54.53 | 29.5 | 84.03 | 17.89 | 7.33 | 25.22 | 6.94 | 2.24 | 9.18 | |
| 23.49 | 14.12 | 37.61 | 42.95 | 21.85 | 64.8 | 17.14 | 6.94 | 24.08 | Av. |

| | | | | | | | | | |
|------|-------|------|-------|-------|-------|--|--|--|--|
| Hys. | 27.86 | Add. | 14.30 | Total | 42.16 | Average losses per
cu. cm. of tower | | | |
|------|-------|------|-------|-------|-------|--|--|--|--|

DATA

| | | | a | | | | | b | | | | | c | | | | |
|-------|-------|-------|----------|------|------|-------|------|----------|------|-------|------|------|------|-------|-------|------|------|
| I_a | I_b | I_c | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 285 | 285 | 285 | 3/16 | 7/32 | 5/16 | 7/16 | 3/8 | 3/8 | 7/16 | 7/16 | 9/32 | 3/16 | 5/32 | 3/16 | 1/4 | 5/32 | 1/8 |
| | | | L = 26.5 | | | | | sp. 1200 | | | | | | | | | |
| | | | Res. 9 | | | | | f = 60 | | | | | | | | | |
| 350 | 350 | 350 | 5/32 | 1/4 | 3/8 | 17/32 | 7/16 | 9/16 | 9/16 | 1/2 | 5/16 | 1/4 | 5/32 | 1/4 | 5/16 | 7/32 | 5/32 |
| | | | L = 26.5 | | | | | sp. 1200 | | | | | | | | | |
| | | | Res. 9 | | | | | f = 60 | | | | | | | | | |
| 445 | 445 | 450 | 1/4 | 3/8 | 9/16 | 3/4 | 9/16 | 11/16 | 3/4 | 11/16 | 7/16 | 5/16 | 3/16 | 11/32 | 11/32 | 1/4 | 5/32 |
| | | | L = 26.5 | | | | | sp. 1200 | | | | | | | | | |
| | | | Res. 9 | | | | | f = 60 | | | | | | | | | |

DATA

| I _a | I _b | I _c | | a | | b | | c | |
|----------------|----------------|----------------|---|------|------|------|------|------|------|
| | | | | max. | eff. | max. | eff. | max. | eff. |
| 285 | 285 | 285 | 1 | .166 | .117 | .333 | .235 | .138 | .097 |
| | | | 2 | .194 | .137 | .388 | .274 | .166 | .117 |
| | | | 3 | .277 | .195 | .388 | .274 | .222 | .157 |
| | | | 4 | .388 | .274 | .250 | .177 | .138 | .097 |
| | | | 5 | .333 | .235 | .166 | .117 | .111 | .078 |
| 350 | 350 | 350 | 1 | .138 | .097 | .500 | .353 | .138 | .097 |
| | | | 2 | .222 | .157 | .500 | .353 | .222 | .157 |
| | | | 3 | .333 | .235 | .444 | .314 | .277 | .195 |
| | | | 4 | .472 | .333 | .277 | .195 | .194 | .137 |
| | | | 5 | .388 | .274 | .222 | .157 | .138 | .097 |
| 445 | 445 | 450 | 1 | .222 | .157 | .611 | .431 | .166 | .117 |
| | | | 2 | .333 | .235 | .666 | .470 | .305 | .215 |
| | | | 3 | .500 | .353 | .611 | .431 | .305 | .215 |
| | | | 4 | .666 | .470 | .388 | .274 | .222 | .157 |
| | | | 5 | .500 | .353 | .277 | .195 | .138 | .097 |

L = 26.5

f = 60

DATA

a

| e | I | IR | e' | IX | (IX) ² | (e') ² | Induced | | |
|------|-------|-------|------|-------|-------------------|-------------------|----------------|------|----------------|
| | | | | | | | E ² | E | e _m |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .137 | .0144 | .104 | .241 | .0323 | .001043 | .058081 | .059124 | .243 | 915 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .274 | .0288 | .208 | .482 | .0645 | .004160 | .232324 | .236484 | .486 | 1825 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .333 | .0351 | .253 | .586 | .0787 | .006194 | .343396 | .349590 | .591 | 2220 |
| .274 | .0288 | .208 | .482 | .0646 | .004160 | .232324 | .236484 | .486 | 1825 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .626 | 2355 |
| .470 | .0495 | .357 | .827 | .1110 | .012321 | .683929 | .696250 | .834 | 3135 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .417 | 1565 |

DATA

a

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $1.6 B_m$ | 10^{-4}
Hy.L. | B_m^2 | Ed.L.
10^{-4} | Total Losses
$10^{-4} w$ |
|----------|-------|------------|----------------|-----------|--------------------|---------|--------------------|-----------------------------|
| 775 | 312 | 2.49415 | 4.00824 | 10192 | 9.17 | 97344 | 3.82 | 12.99 |
| 915 | 379 | 2.57864 | 4.123984 | 13305 | 11.97 | 143641 | 4.43 | 16.40 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| Av. | 526 | 2.7210 | 4.3536 | 22570 | 20.3 | 276676 | 8.57 | 28.87 |
| 650 | 269 | 2.34044 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| 2220 | 920 | 2.96379 | 4.742064 | 55254 | 49.72 | 846400 | 26.25 | 75.97 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| Av. | 605 | 2.7818 | 4.45088 | 28240 | 25.41 | 366025 | 11.35 | 36.76 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| 3135 | 1300 | 3.11394 | 4.982304 | 96010 | 86.40 | 1690000 | 52.4 | 138.80 |
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| Av. | 800 | 2.9031 | 4.64496 | 44150 | 39.73 | 640000 | 19.85 | 59.58 |

DATA

b

| e | I | IR | e' | IX | (IX) ² | (e') ² | Induced | | |
|------|-------|------|------|-------|-------------------|-------------------|----------------|------|----------------|
| | | | | | | | E ² | E | e _m |
| .235 | .0248 | .179 | .414 | .0556 | .003091 | .171396 | .174487 | .417 | 1565 |
| .274 | .0288 | .208 | .482 | .0645 | .004160 | .232324 | .236484 | .486 | 1825 |
| .274 | .0288 | .208 | .482 | .0645 | .004160 | .232324 | .236489 | .486 | 1825 |
| .177 | .0186 | .134 | .311 | .0417 | .001738 | .096721 | .098459 | .313 | 1175 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| | | | | | | | | | |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .626 | 2355 |
| .353 | .0372 | .268 | .621 | .0834 | .006956 | .385641 | .392597 | .626 | 2355 |
| .314 | .0331 | .239 | .553 | .0742 | .005506 | .305809 | .311315 | .558 | 2100 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| | | | | | | | | | |
| .431 | .0454 | .327 | .758 | .101 | .010010 | .574564 | .584574 | .764 | 2875 |
| .470 | .0495 | .357 | .827 | .111 | .012321 | .683929 | .696250 | .834 | 3135 |
| .431 | .0454 | .327 | .758 | .101 | .010010 | .574564 | .584574 | .764 | 2875 |
| .274 | .0288 | .208 | .482 | .0645 | .004160 | .232324 | .236484 | .486 | 1825 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |

DATA

b

| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $1.6 B_m$ | 10^{-4}
Hy. L. | B_m^2 | Ed.L.
10^{-4} | Total Losses
10^{-4} |
|----------|-------|------------|----------------|-----------|---------------------|---------|--------------------|---------------------------|
| 1565 | 648 | 2.81158 | 4.498528 | 31517 | 28.36 | 419904 | 13.0 | 41.36 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 236196 | 17.7 | 53.92 |
| 1175 | 486 | 2.68664 | 4.298664 | 19888 | 17.89 | 236196 | 7.33 | 25.22 |
| 775 | 320 | 2.49415 | 4.00824 | 10192 | 9.17 | 102400 | 3.82 | 12.99 |
| Av. | 593 | 2.7731 | 4.43696 | 27340 | 24.60 | 351649 | 10.9 | 35.50 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| 2355 | 975 | 2.98900 | 4.7824 | 60590 | 54.53 | 950625 | 29.5 | 84.03 |
| 2100 | 870 | 2.93952 | 4.703232 | 50496 | 45.44 | 756900 | 23.5 | 68.94 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| Av. | 758 | 2.8797 | 4.60752 | 40500 | 36.45 | 574564 | 17.8 | 54.25 |
| 2870 | 1190 | 3.07555 | 4.92088 | 83347 | 75.01 | 1416100 | 43.9 | 118.91 |
| 3135 | 1300 | 3.88649 | 4.982304 | 96010 | 86.40 | 1690000 | 52.4 | 138.80 |
| 2870 | 1190 | 3.07555 | 4.92088 | 83347 | 75.01 | 1416100 | 43.9 | 118.91 |
| 1825 | 755 | 2.87795 | 4.60472 | 40250 | 36.22 | 570025 | 17.7 | 53.92 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| Av. | 994 | 2.9974 | 4.79584 | 62500 | 56.25 | 988036 | 30.65 | 86.90 |

DATA

c

| e | I | IR | $\frac{e'}{e+IR}$ | IX | $(IX)^2$ | $(e')^2$ | E^2 | Induced
E | a_m |
|------|-------|-------|-------------------|-------|----------|----------|---------|--------------|-------|
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |
| .078 | .0082 | .0592 | .137 | .0183 | .000334 | .018769 | .019103 | .139 | 523 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .195 | .0205 | .148 | .343 | .0460 | .002116 | .117649 | .119765 | .346 | 1300 |
| .137 | .0144 | .104 | .241 | .0323 | .001043 | .058081 | .059124 | .243 | 915 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |
| .117 | .0123 | .088 | .205 | .0275 | .000756 | .042025 | .042781 | .206 | 775 |
| .215 | .0226 | .155 | .370 | .0506 | .002560 | .136900 | .139460 | .373 | 1400 |
| .215 | .0226 | .155 | .370 | .0506 | .002560 | .136900 | .139460 | .373 | 1400 |
| .157 | .0165 | .119 | .276 | .0370 | .001369 | .076176 | .077545 | .278 | 1045 |
| .098 | .0103 | .0744 | .172 | .0231 | .000533 | .029584 | .030117 | .173 | 650 |

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|----------|-------|------------|----------------|-------------|-------------------------|--------------------|-----------|-------------|
| ϕ_m | B_m | $\log B_m$ | $1.6 \log B_m$ | $B_m^{1.6}$ | 10^{-4} Hy.L. | B_m^2 | 10^{-4} | $10^{-4} w$ |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| 775 | 312 | 2.49415 | 4.00824 | 10192 | 9.17 | 97344 | 3.82 | 12.99 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| 523 | 216 | 2.33445 | 3.73512 | 5434 | 4.89 | 46656 | 1.44 | 6.38 |
| Av. | 300 | 2.4771 | 3.96336 | 9190 | 8.27 | 90000 | 2.79 | 11.06 |
| | | | | | | | | |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 1300 | 538 | 2.73078 | 4.369248 | 23400 | 21.06 | 289444 | 8.97 | 30.03 |
| 915 | 378 | 2.57864 | 4.123984 | 13305 | 11.97 | 143641 | 4.43 | 16.40 |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| Av. | 377 | 2.5763 | 4.12208 | 13243 | 11.91 | 142129 | 4.41 | 16.32 |
| | | | | | | | | |
| 775 | 312 | 2.49415 | 4.00824 | 10192 | 9.17 | 97344 | 3.82 | 12.99 |
| 1400 | 580 | 2.76343 | 4.421488 | 26392 | 23.75 | 336400 | 10.04 | 33.79 |
| 1400 | 580 | 2.76343 | 4.421488 | 26392 | 23.75 | 336400 | 10.04 | 33.79 |
| 1045 | 433 | 2.63649 | 4.218384 | 16535 | 14.88 | 187489 | 5.82 | 20.70 |
| 650 | 269 | 2.42975 | 3.8876 | 7720 | 6.94 | 72361 | 2.24 | 9.18 |
| Av. | 435 | 2.6385 | 4.2216 | 16656 | 14.99 | 189225 | 5.87 | 20.86 |

DATA

Summary of Results

$$L = 26.5''$$

| a | | | b | | | c | | | |
|------------|------------|------------|------------|------------|------------|------------|------------|------------|-----------|
| W_h | W_e | W_t | W_h | W_e | W_t | W_h | W_e | W_t | |
| $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | $10^{-4}w$ | |
| 9.17 | 3.82 | 12.99 | 28.36 | 13.0 | 41.36 | 6.94 | 2.24 | 9.18 | |
| 11.97 | 4.43 | 16.40 | 36.22 | 17.7 | 53.92 | 9.17 | 3.82 | 12.99 | $I_a=285$ |
| 21.06 | 8.97 | 30.03 | 36.22 | 17.7 | 53.92 | 14.88 | 5.82 | 20.70 | $I_b=285$ |
| 36.22 | 17.7 | 53.92 | 17.89 | 7.33 | 25.22 | 6.94 | 2.24 | 9.18 | $I_c=285$ |
| 28.36 | 13.0 | 41.36 | 9.17 | 3.82 | 12.99 | 4.89 | 1.44 | 6.33 | |
| 20.3 | 8.57 | 28.87 | 24.60 | 10.9 | 35.50 | 8.27 | 2.79 | 11.06 | Av. |

Hys. 17.72 Edd. 7.42 Total 25.14 Average losses per
cu. cm. of tower

| | | | | | | | | | |
|-------|-------|-------|-------|------|-------|-------|------|-------|-----------|
| 6.94 | 2.24 | 9.18 | 54.53 | 29.5 | 84.03 | 6.94 | 2.24 | 9.18 | |
| 14.88 | 5.82 | 20.70 | 54.53 | 29.5 | 84.03 | 14.88 | 5.82 | 20.70 | $I_a=350$ |
| 28.36 | 13.0 | 41.36 | 45.44 | 23.5 | 68.94 | 21.06 | 8.97 | 30.03 | $I_b=350$ |
| 49.72 | 26.25 | 75.97 | 21.06 | 8.97 | 30.03 | 11.97 | 4.43 | 16.40 | $I_c=350$ |
| 36.22 | 17.7 | 53.92 | 14.88 | 5.82 | 20.70 | 6.94 | 2.24 | 8.18 | |
| 25.41 | 11.35 | 36.76 | 36.45 | 17.8 | 54.25 | 11.91 | 4.41 | 16.32 | Av. |

Hys. 24.59 Edd. 11.19 Total 35.78 Average losses per
cu. cm. of tower

| | | | | | | | | | |
|-------|-------|--------|-------|-------|--------|-------|-------|-------|-----------|
| 14.88 | 5.82 | 20.70 | 75.01 | 43.9 | 118.91 | 9.17 | 3.82 | 12.99 | |
| 28.36 | 13.0 | 41.36 | 86.40 | 52.4 | 138.80 | 23.75 | 10.04 | 33.79 | $I_a=445$ |
| 54.53 | 29.5 | 84.03 | 75.01 | 43.9 | 118.91 | 23.75 | 10.04 | 33.79 | $I_b=445$ |
| 86.40 | 52.4 | 138.80 | 36.22 | 17.7 | 53.92 | 14.88 | 5.82 | 20.70 | $I_c=445$ |
| 28.36 | 13.0 | 41.36 | 21.06 | 8.97 | 30.03 | 6.94 | 2.24 | 9.18 | |
| 39.73 | 19.85 | 59.58 | 56.25 | 30.65 | 86.90 | 14.99 | 5.87 | 20.86 | Av. |

Hys. 36.99 Edd. 18.79 Total 55.78 Average losses per

The following curves are loss distance curves. They show the distribution of losses at various points along the legs.

The area under each curve was measured and when divided by the length it gave the same losses as obtained by computation when using the average flux.

due to different Currents

15

14

13

12

11

10

9

8

7

6

5

4

3

2

1

.25

.5

75

1.0

Distance from the Upper Corner on Leg A.

440 amps.

360 amps.

310 amps.

230 amps

Eddy current Loss in Leg A
due to Different Currents.

Milliwatts
per CO.

10

9

8

7

6

5

4

3

2

1

440 amps.

360 amps

310 amps

230 amps

.25

.5

.75

1

Distance from the Upper Corner on Leg A.

Total Losses in leg A
due to different currents.

Milliwatts
per CC.

24

22

20

18

16

14

12

10

8

6

4

2

440 amps.

360 amps.

310 amps.

230 amps.

.25

.5

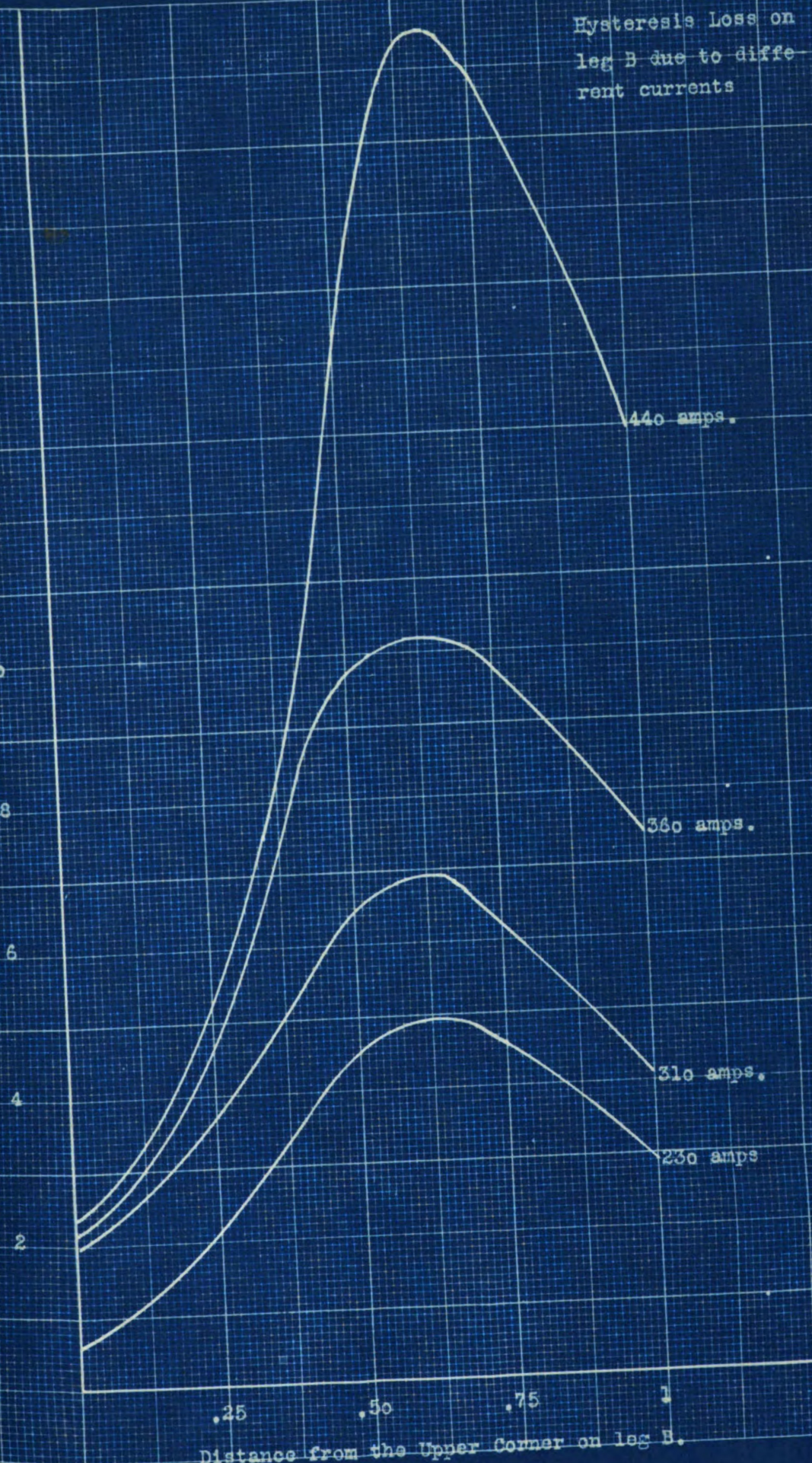
.75

1

Distance from the upper Corner on leg A.

Milliwatts
per cc.

Hysteresis Loss on
leg B due to diffe-
rent currents



Distance from the Upper Corner on leg B.

Milliwatts
per cc.

Eddy Current Loss on Leg B
due to different currents.

14

12

10

8

6

4

2

440 amps.

360 amps

310 amps.

230 amps.

.25

.5

.75

1.5

Distance from the Upper Corner
of leg B.

Total Losses on Leg B
due to different currents.



Hysteresis Loss in Leg C at different points
due to different currents,
conductor at 19.5 in.

Milliwatts
per cc.

4

3

2

1

440 amps.

360 amps.

310 amps.

250 amps.

.25

.50

.75

1.0

Distance from one corner expressed
as a fraction of the total length
of leg C.

Eddy Current Loss in Leg C

Milliwatts
per cc.

2

1

440 amps.
360 amps.
310 amps.
230 amps.

.25

.50

.75

1.0

Distance from one corner.

Milliwatts
per cc.

Total Losses in Leg C
due to different currents

6

5

4

3

2

1

440 amps.

360 amps.

310 amps

230 amps

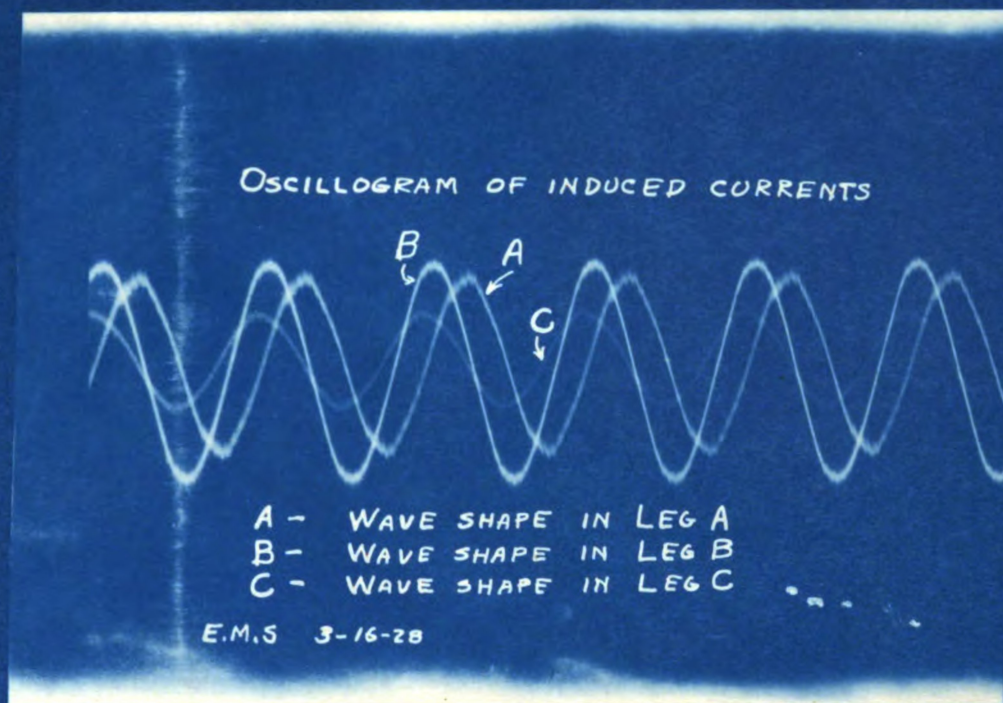
.25

.5

.75

1.0

Distance from one corner on C.



An oscillogram of the induced currents on the three legs.

Results from experiment

$$\frac{(360)^n}{(230)} = \frac{86}{38.95}$$

$$n (2.556303 - 2.361728) = 1.934498 - 1.591065$$

$$.194575 n = .343433$$

$$n = 1.765$$

$$\frac{(440)^n}{(360)} = \frac{120}{86}$$

$$n (2.643453 - 2.556303) = 2.082785 - 1.934498$$

$$.087150 n = .148287$$

$$n = 1.701$$

$$\frac{(440)^n}{(230)} = \frac{120}{38.95}$$

$$n (2.643453 - 2.361728) = 2.082785 - 1.591065$$

$$.281725 n = .491720$$

$$n = 1.745$$

$$\frac{(475)^n}{(360)} = \frac{81}{49}$$

$$n (2.676694 - 2.556303) = 1.908485 - 1.690196$$

$$.120391 n = .218289$$

$$n = 1.813$$

$$\frac{(475)^n}{(320)} = \frac{81}{42}$$

$$n (2.676694 - 2.507856) = 1.908485 - 1.623249$$

$$.168838 n = .285236$$

$$n = 1.689$$

$$\text{Average } n = (1.765 + 1.701 + 1.745 + 1.813 + 1.689)/5$$

$$= 1.742$$

\mathcal{C}_1 and \mathcal{C}_2 are the two components of \mathcal{C} and $\mathcal{C}_1 \cap \mathcal{C}_2 = \emptyset$.
 If \mathcal{C}_1 and \mathcal{C}_2 are both connected, then \mathcal{C} is connected.
 If \mathcal{C}_1 and \mathcal{C}_2 are both disconnected, then \mathcal{C} is disconnected.
 If \mathcal{C}_1 is connected and \mathcal{C}_2 is disconnected, then \mathcal{C} is disconnected.

Let \mathcal{C} be a connected component of \mathcal{G} .
 If \mathcal{C} is a cycle, then \mathcal{C} is a cycle.
 If \mathcal{C} is not a cycle, then \mathcal{C} is a tree.

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 If \mathcal{C} is a cycle, then \mathcal{C} is a cycle.
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 If \mathcal{C} is a cycle, then \mathcal{C} is a cycle.
 If \mathcal{C} is not a cycle, then \mathcal{C} is a tree.

Reducing losses to same currents at different distances

$$1.742 (\log 360 - \log 285) = \log 86 - \log x$$

$$1.742 (2.556303 - 2.454845) = 1.934498 - \log x$$

$$1.742 (.101458) = 1.934498 - \log x$$

$$.176740 = 1.934498 - \log x$$

$$\log x = 1.757758$$

$$x = 57.247$$

$$1.742 (\log 360 - \log 200) = \log 86 - \log 2$$

$$1.742 (2.556303 - 2.301030) = 1.934498 - \log x$$

$$1.742 (.255273) = 1.934498 - \log x$$

$$.444685 = 1.934498 - \log x$$

$$\log x = 1.489813$$

$$x = 30.89$$

$$1.742 (\log 360 - \log 285) = \log 49.22 - \log x$$

$$1.742 (2.556303 - 2.454845) = 1.692142 - \log x$$

$$.176740 = 1.692142 - \log x$$

$$\log x = 1.515402$$

$$x = 32.76$$

$$1.742 (\log 360 - \log 200) = \log 49.22 - \log x$$

$$.444685 = 1.692142 - \log x$$

$$\log x = 1.247457$$

$$x = 17.67$$

$$1.742 (\log 440 - \log 360) = \log x - \log 49.22$$

$$1.742 (2.643453 - 2.556303) = \log x - 1.692142$$

$$1.742 (.087150) = \log x - 1.692142$$

$$.151815 = \log x - 1.692142$$

$$\log x = 1.843957$$

$$x = 69.81$$

$$1.742 (\log 360 - \log 285) = \log x - \log 25.14$$

$$.176740 = \log x - 1.400365$$

$$\log x = 1.577105$$

$$x = 37.77$$

$$1.742 (\log 360 - \log 200) = 1.577105 - \log x$$

$$.444685 = 1.577105 - \log x$$

$$\log x = 1.132420$$

$$x = 13.56$$

$$1.742 (\log 440 - \log 360) = \log x - 1.577105$$

$$.151815 = \log x - 1.577105$$

$$\log x = 1.728920$$

$$x = 53.57$$

The combination of those results are shown in the following table.

Reducing to Four Different Currents

| I | Dis-
tance | Losses
$10^{-4} w$ | Dis-
tance | Losses
$10^{-4} w$ | Dis-
tance | Losses
$10^{-4} w$ |
|-----|---------------|-----------------------|---------------|-----------------------|---------------|-----------------------|
| 360 | 19.5 | 86 | 24 | 49.22 | 26.5 | 37.77 |
| 285 | 19.5 | 57.24 | 24 | 32.76 | 26.5 | 25.14 |
| 200 | 19.5 | 30.89 | 24 | 17.67 | 26.5 | 13.56 |
| 440 | 19.5 | 120.88 | 24 | 69.81 | 26.5 | 53.57 |

Four different currents were chosen in such a manner that the losses due to one of these currents are known at one distance while those due to the other are known for some other distance. By using the formula

$$\left(\frac{I_1}{I_2} \right)^{1.742} = \frac{L_1}{L_2}$$

the losses for the various currents were found at different distances.

From the Table we get

$$\frac{(19.5)^x}{(24)} = \frac{49.22}{86}$$

$$x(\log 24 - \log 19.5) = \log 86 - \log 49.22$$

$$x(1.380211 - 1.290035) = 1.934498 - 1.692142$$

$$.090186 x = 2.42356$$

$$x = 2.687$$

$$\frac{(19.5)^x}{(24)} = \frac{17.67}{30.89}$$

$$.090186 x = 1.247237 - 1.489818$$

$$.090186 x = .242581$$

$$x = 2.689$$

$$\frac{(19.5)^x}{(24)} = \frac{32.76}{57.24}$$

$$.090186 x = 1.757758 - 1.515402$$

$$.090186 x = .242356$$

$$x = 2.687$$

$$\frac{(19.5)^x}{(26.5)} = \frac{37.77}{86}$$

$$x[1.423246 - 1.290035] = 1.934498 - 1.577105$$

$$.133211 x = .357393$$

$$x = 2.683$$

$$\frac{(19.5)^x}{(26.5)} = \frac{25.14}{57.24}$$

$$.133211 x = 1.757758 - 1.400365$$

$$.133211 x = .357393$$

$$x = 2.683$$

QUESTION

1. The following table shows the number of people who attended the 2010 World Cup in South Africa. The table is divided into two parts: the first part shows the number of people who attended the 2010 World Cup in South Africa, and the second part shows the number of people who attended the 2010 World Cup in South Africa.

2. The following table shows the number of people who attended the 2010 World Cup in South Africa. The table is divided into two parts: the first part shows the number of people who attended the 2010 World Cup in South Africa, and the second part shows the number of people who attended the 2010 World Cup in South Africa.

3. The following table shows the number of people who attended the 2010 World Cup in South Africa. The table is divided into two parts: the first part shows the number of people who attended the 2010 World Cup in South Africa, and the second part shows the number of people who attended the 2010 World Cup in South Africa.

4. The following table shows the number of people who attended the 2010 World Cup in South Africa. The table is divided into two parts: the first part shows the number of people who attended the 2010 World Cup in South Africa, and the second part shows the number of people who attended the 2010 World Cup in South Africa.

5. The following table shows the number of people who attended the 2010 World Cup in South Africa. The table is divided into two parts: the first part shows the number of people who attended the 2010 World Cup in South Africa, and the second part shows the number of people who attended the 2010 World Cup in South Africa.

$$\frac{(19.5)^x}{(26.5)} = \frac{13.56}{30.89}$$

$$.133211 x = 1.489813 - 1.132420$$

$$.133211 x = .35739$$

$$x = 2.683$$

$$\frac{13.56}{17.67} = \left(\frac{24}{26.5} \right)^x$$

$$1.247457 - 1.132420 = (1.423246 - 1.380211)x$$

$$.115037 = .043035$$

$$x = 2.673$$

From the preceding results it is seen that x has a constant value.

$$\text{Therefore } x = (2.687 + 2.689 + 2.687 + 2.683 + 2.683 + 2.673) \frac{1}{6}$$

$$x = 2.683$$

Deduction of laws

From results it is seen that for a constant distance

$$\left(\frac{I_1}{I_2} \right)^m = \frac{L_1}{L_2} \quad (1)$$

or more exactly

$$\left(\frac{I_1}{I_2} \right)^{1.742} = \frac{L_1}{L_2} \quad (2)$$

and for a constant current

$$\left(\frac{D_1}{D_2} \right)^x = \frac{L_2}{L_1} \quad (3)$$

or more exactly

$$\left(\frac{D_1}{D_2} \right)^{2.683} = \frac{L_2}{L_1} \quad (4)$$

Laws (2) and (4) give the relation between currents, distances, and losses

Thus

$$\left(\frac{D_1}{D_2} \right)^x = \left(\frac{I_2}{I_1} \right)^n \quad (5)$$

or

$$D_2^x I_2^n = D_1^x I_1^n \quad (6)$$

showing that the same loss is obtained when current I_1 becomes I_2 if D_1 becomes D_2 . The value of D_2 is found from (5) or (6).

From the deduced laws let us find the losses due to a unit current at a unit distance. First find losses at distance 19.5'' due to unit current.

From (2)

$$\left(\frac{I_1}{I_2}\right)^{1.742} = \frac{L_1}{L_2}$$

$$\left(\frac{1}{200}\right)^{1.742} = \frac{x}{30.89 \times 10^{-4}}$$

$$\log 200 = 2.301030$$

$$1.742 \log 200 = 4.008394$$

$$(200)^{1.742} = 10148$$

$$\frac{1}{10148} = \frac{x}{30.89 \times 10^{-4}}$$

$$x = 3.045 \times 10^{-7}$$

Then find losses at distance of 1 inch

From (4)

$$\left(\frac{19.5}{1}\right)^{2.683} = \frac{x}{3.045 \times 10^{-7}}$$

$$\log 19.5 = 1.290035$$

$$2.683 \log 19.5 = 3.461163$$

$$(19.5)^{2.683} = 2891.8$$

$$2891.8 = \frac{x}{3.045 \times 10^{-7}}$$

$$x = 8.805531 \times 10^{-4}$$

$$\left(\frac{1}{360}\right)^{1.742} = \frac{x}{86}$$

$$\log 360 = 2.556303$$

$$1.742 \log 360 = 4.453079$$

$$(360)^{1.742} = 28384$$

$$\frac{1}{28384} = \frac{x}{86}$$

$$x = 3.029 \times 10^{-7}$$

Then at 1 inch distance it is

$$\left(\frac{19.5}{1}\right)^{2.683} = \frac{x}{3.029 \times 10^{-7}}$$

$$2891.8 = \frac{x}{3.029 \times 10^{-7}}$$

$$x = 8.759 \times 10^{-4}$$

$$\left(\frac{1}{285}\right)^{1.742} = \frac{x}{57.24 \times 10^{-4}}$$

$$\log 285 = 2.454845$$

$$1.742 \log 285 = 4.276339$$

$$(285)^{1.742} = 18895$$

$$\frac{1}{18895} = \frac{x}{57.24 \times 10^{-4}}$$

$$x = 3.029$$

Then at 1 inch distance it is

$$\left(\frac{19.5}{1}\right)^{2.683} = \frac{x}{3.029 \times 10^{-7}}$$

$$x = 8.759 \times 10^{-4}$$

The average x is then 8.759×10^{-4}

Therefore, if it is desired to find the losses due to a current I, D inches from the tower use the following formula

$$L_T = 8.759 \times 10^{-4} \frac{(I)^{1.742}}{(D)^{2.683}}$$

As a check assume $I = 440$

$$D = 24''$$

$$L_T = 8.759 \times 10^{-4} \frac{(440)^{1.742}}{(24)^{2.683}}$$

$$\log 440 = 2.643453$$

$$1.742 \log 440 = 4.604895$$

$$(440)^{1.742} = 40262$$

$$\log 24 = 1.380211$$

$$2.683 \log 24 = 3.703106$$

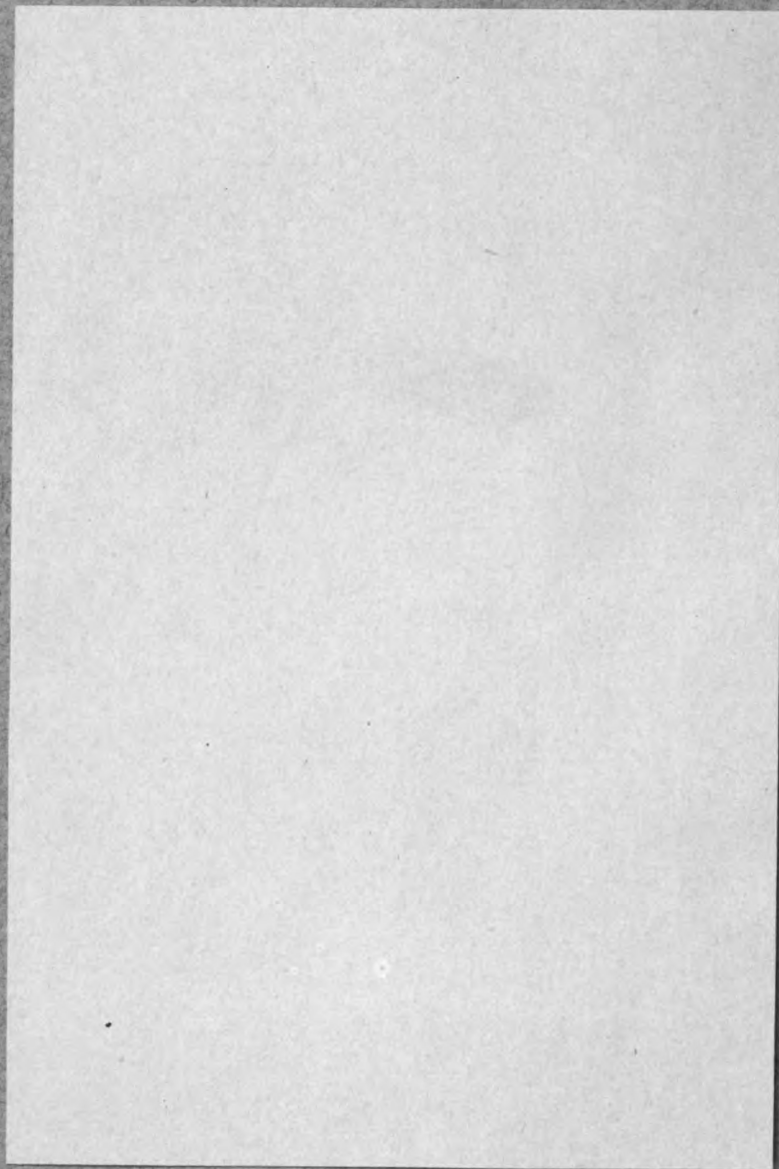
$$(24)^{2.683} = 5047.8$$

$$L_T = 8.759 \times 10^{-4} \frac{40262}{5047.8}$$

$$= 8.759 \times 7.97 \times 10^{-4}$$

$$= 69.80 \times 10^{-4} \text{ as checked with } 69.81 \times 10^{-4}$$

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