TEST OF A DELCO LIGHTING PLANT

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Test of a delco lighting plant
TEST OF A
DELCO LIGHTING PLANT

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FOREWORD.

The subject presented herein is in three parts.

Part One gives a general description of the plant and its parts. Part Two deals with the determination of the overall efficiency and the auxiliary tests which accompany this determination. Part Three discusses the methods used and the results obtained in approximating several of the losses in the plant; and the auxiliary tests necessary in determining these losses.
ACKNOWLEDGEMENTS.

The authors desire to express their indebtedness to Prof. E. E. Freeman, Prof. J. E. Snow, and Assoc. Prof. D. P. Moreton for their cooperation and helpful suggestions. They also wish to thank the Domestic Engineering Co. of Dayton, Ohio for the use of their plant.

L.E.G.
E.D.F.
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Part 1.

A General Description of the Plant and its Parts.
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Description of the Delco Lighting Plant.

The Delco-Light Plant consists of an air-cooled gasoline engine directly connected to an electric generator, with the switchboard mounted on top of the generator, on which are the necessary controlling instruments. These are all in one unit and may be called the engine unit. The second unit is the storage batteries consisting of sixteen glass cells.

The Delco-Light engine is a four cycle valve-in-the-head type with mechanically operated intake and exhaust valves.

The crank case is made of cast-iron, cast in one piece with an inside shell, which forms the crank case proper and an outer shell which provides a passage for the cooling air. The outside shell has a flange cast around the upper edge to which the draft tube is attached. The inside shell has an opening at the top machined
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to fit the cylinder.

A simple mixing valve is used as shown in Fig. 1. The air adjustment may be made by turning the knurled cap so as to increase or decrease the size of the openings. There is also a check valve on the mixing valve to prevent the gasoline from running back into the tank during the interval of time between explosions of the engine.

The method of cooling is accomplished by building the flywheel in the form of a fan, as shown in Fig. 2, which throws the air off at its face or periphery, creating a suction which draws air down past the cylinder. Surrounding the cylinder is a drawn sheet metal draft tube, the purpose of which is to keep the air that is drawn down through this tube as close to the cylinder as possible. It is tapered toward the top, and air is drawn down
Fig. 1 - Mixing Valve.

Fig. 2 - Flywheel.
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past the heated cylinder at a high velocity, providing effective cooling without the use of an additional fan. The path of the air which cools the engine is shown in Fig. 3.

The cylinder (Fig. 4) and cylinder head are covered with fins which distribute the heat over a large area, thereby giving ample radiating surface to the cooling air.

The gasoline tank, which is attached to the draft tube, has a capacity of one gallon; this is sufficient to run the engine for five hours.

The crank case holds about two quarts of oil. Dipping into this oil, is a large gear which is driven by a smaller gear on the crank shaft. This gear splashes oil upon the bearings within the crank case; and at the end of each downward stroke, oil is splashed upon the piston and carried upward on the
Fig. 3 - Air-passage Diagram.
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piston, lubricating the cylinder walls. On the ends of the crank shaft, are oil throwing rings, which prevent the oil from following the crank shaft out to the flywheel on one end, or the armature on the other.

The crank shaft is a heavy drop forging, and is provided with counterbalance weights. It is mounted with a ball bearing at the generator end to receive the radial and end thrust load, and a roller bearing at the flywheel end which will accommodate any contraction or expansion of the shaft due to temperature variations.

The piston is made of aluminum alloy, and is fitted with three piston rings. These are cast-iron and of the eccentric type; this produces uniform pressure against the cylinder walls. Two oil carrying grooves are turned in the lower end of the piston.
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On the side of the crank case, is a projection containing the breather and oil filler. The breather is packed with excelsior to remove the smoke and oil from the gases passing through it. The oil filler is cast on to the same piece as the breather. The breather and oil filler are shown in Fig. 10.

The exhaust pipe is provided with a sheet-iron muffler, and is tapped to fit a one inch pipe.

The ignition system consists of the ignition coil, with a resistance unit in its end and a condenser in its base; the spark plug; and the timer contacts. The timer or ignition breaker is shown in Fig. 5. It consists of a set of contacts operated by a central cam. This timer cam is on the end of the cam shaft, and is driven at one-half crank-
Fig. 4 - Cylinder.

Fig. 5 - Timer.
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Shift speed by spiral gears (Fig. 7); the contacts are made of tungsten.

The switchboard (Figs. 8 & 9), rigidly attached to the generator frame, is made of asbestos fibre, an insulating material which is not brittle. On the front are mounted the starting, stopping, and power switches; the battery gauge (ampere hour meter); and three fuses, one in the generator circuit and two in the load circuit.

When the starting lever, which is located in about the center of Fig. 7, is pulled down, the ignition circuit is closed and a short circuiting contact is opened, which cuts in the series field winding on the generator, producing a high starting torque. The series winding is shorted out as soon as the hand is removed from the switch lever. The lever is held up magnetically, as soon as the engine comes up to speed.
Fig. 6 - Armature.

Fig. 7 - Cam Shaft.
and the generator is charging the battery.

The light and power switch is the two pole, single throw, knife switch located at the side of the starting switch above the two small fuses. Opening this switch, disconnects the light and power circuit. The generator can be run with this circuit open; all of the generated current then goes to the battery. The stopping switch is also a double pole, single throw, knife switch, and is used for emergency purposes. One side of this switch opens the ignition circuit, and the other the battery circuit.

The storage battery consists of sixteen cells. It is a 32 volt, 80 ampere hour battery. Each cell consists of positive and negative plates, spaced by hard rubber and wood separators. The jars are made of heavy glass, and have a water line guard marked
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upon them. One of the cells of the battery is a pilot cell; this has two pilot balls which are in a small compartment blown in the glass. The specific gravity of the electrolyte causes the balls to float or sink, indicating the condition of charge of the battery.
Fig. 6 - Front of Switchboard.
Fig. 9 - Back of Switchboard.
Fig. 10 - Outside View of Delco-Light Plan.
Part 2.

The Determination of the Overall Efficiency and the Auxiliary Tests which accompany this Determination.
Overall Efficiency Test of Delco Light Plant.
Key to Part Two.

G. - Weight in grams of gasoline used per run.
H. - B.t.u. in gasoline input.
I_l - Line Current.
I_{tot} - Total Current.
I_b. - Battery Current.
t. - time in seconds.

V. - Voltage across Switchboard Terminals.
W_x - Watts output.
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Determination of calorific value of the gasoline used.

Before making any tests on the Delco Light Plant, it was necessary to determine the calorific value of the fuel used in making these tests. The fuel used was standard Red Crown Gasoline. Its calorific value was determined by means of a bomb calorimeter. In order to use this method, it was necessary to reduce the evaporation of the gasoline, while the bomb was being made up, to a minimum. This was accomplished by putting 0.5103 grams of chemically pure naphthalene in the pan. Then a sample of the gasoline used was drawn into a pipette and .49 c.c. allowed to drop into the pan. This immediately soaked into the naphthalene, thus allowing only a negligible amount of gasoline to evaporate. The pan was then placed in the bomb, and the cover tightened until the bomb was air-tight. About 20
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Atmospheres of oxygen were forced into the bomb, which was then placed in a calorimeter containing 2200 grams of water. A Beckman thermometer and a stirrer were placed in the water, and the latter stirred until its temperature remained constant. Then 110 volts were impressed across the terminals of the bomb through a resistance of 50 ohms, the electric circuit being completed inside the bomb by a fine iron fuse wire, which passed through the gasoline soaked naphthalene.

The heating of the iron wire, due to the current passing through it, caused a violent combustion of the gasoline and naphthalene in the oxygen atmosphere. The result was that heat was liberated, and consequently the temperature of the water in the calorimeter rose. The temperature was noted on the Beckman thermometer every 30 seconds, until the maximum
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The test was designed to measure the heat generated during combustion of gasoline. The temperature was reached. The rate of fall in temperature was then noted for a period of 4 minutes. The radiation loss was calculated according to Bates - "Calorimetry," as shown in data sheet No. 2. Adding this to the observed maximum temperature gives the corrected maximum temperature. To obtain the corrected water weight, the water equivalent of the bomb was added to the weight of water in the calorimeter, making the corrected water weight 2712 grams or 5.973 lbs. Since the specific heat of water was assumed unity, the heat given off during combustion was

\[ B.t.u. = \frac{W}{C_w} (T_1 - T_2) \]

where B.t.u. is the heat given off during combustion, \( W \), the corrected weight of the water in pounds, and \( (T_1 - T_2) \) the rise in temperature in degrees Fahrenheit. The heat given off by the combustion of the gasoline was
**Data Sheet No. 1.**

*Calibration of Red Crown Gasoline used in Test of a Delco Light Plant.*

Grams. wt. of pan and napthalene  = 6.5603

Grams. wt. of pan  = 6.0500

Grams. wt. of napthalene  = 0.5103

Degrees Baume  = 56.00

<table>
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<th>Time in Minutes</th>
<th>Beckman Temperature</th>
<th>Difference in degrees. Cent.</th>
</tr>
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<tbody>
<tr>
<td>0.0</td>
<td>0.795</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>0.800</td>
<td>0.005</td>
</tr>
<tr>
<td>1.0</td>
<td>0.800</td>
<td>0.000</td>
</tr>
<tr>
<td>1.5</td>
<td>0.800</td>
<td>0.000</td>
</tr>
<tr>
<td>2.0</td>
<td>0.800</td>
<td>0.000</td>
</tr>
<tr>
<td>2.5</td>
<td>1.900</td>
<td>1.100-Explosion had occurred</td>
</tr>
<tr>
<td>3.0</td>
<td>3.620</td>
<td>1.720 degrees Baume occurred</td>
</tr>
<tr>
<td>3.5</td>
<td>3.910</td>
<td>1.290 degrees Baume occurred</td>
</tr>
<tr>
<td>4.0</td>
<td>3.990</td>
<td>0.080</td>
</tr>
<tr>
<td>4.5</td>
<td>4.000</td>
<td>0.010</td>
</tr>
<tr>
<td>5.0</td>
<td>3.995</td>
<td>0.005-4.5 minutes</td>
</tr>
<tr>
<td>5.5</td>
<td>3.980</td>
<td>0.015 Ar. rate</td>
</tr>
<tr>
<td>6.0</td>
<td>3.970</td>
<td>0.015 degrees Baume occurred after 4.5 minutes</td>
</tr>
<tr>
<td>6.5</td>
<td>3.960</td>
<td>0.015 is 0.012</td>
</tr>
<tr>
<td>7.0</td>
<td>3.945</td>
<td>0.015 degrees Baume occurred after 4.5 minutes</td>
</tr>
<tr>
<td>7.5</td>
<td>3.933</td>
<td></td>
</tr>
<tr>
<td>8.0</td>
<td>3.915</td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td>3.910</td>
<td></td>
</tr>
<tr>
<td>9.0</td>
<td>3.892</td>
<td>0.018</td>
</tr>
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## Data Sheet No. 2.

**Calibration of Red Crown Gasoline used in Test of a Delco Light Plant.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
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<tr>
<td>Room Temperature deg. F.</td>
<td>86.0</td>
</tr>
<tr>
<td>Specific gravity of gasoline</td>
<td>0.7527</td>
</tr>
<tr>
<td>Water equivalent of bomb in grs.</td>
<td>512.0</td>
</tr>
<tr>
<td>Weight of water in calorimeter in grs.</td>
<td>2200.0</td>
</tr>
<tr>
<td>Correct wt. of water in pounds</td>
<td>5.973</td>
</tr>
<tr>
<td>Radiation loss in degrees Cent.</td>
<td>0.018</td>
</tr>
<tr>
<td>Corrected Temp. rise in deg. F.</td>
<td>5.792</td>
</tr>
<tr>
<td>B.t.u. generated</td>
<td>34.595</td>
</tr>
<tr>
<td>B.t.u. in napthalene per lt.</td>
<td>17,442.0</td>
</tr>
<tr>
<td>B.t.u. in napthalene in test</td>
<td>19.602</td>
</tr>
<tr>
<td>B.t.u. in .49 c.c. gasoline</td>
<td>14.993</td>
</tr>
<tr>
<td>B.t.u. per c.c. gasoline</td>
<td>30.600</td>
</tr>
<tr>
<td>B.t.u. per gram gasoline</td>
<td>40.65</td>
</tr>
<tr>
<td>B.t.u. per pound gasoline</td>
<td>18,455.1</td>
</tr>
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equal to the total heat minus the heat given off by the combustion of the naphthalene. The heat given off by the gasoline is shown in data sheet No. 2 to be 14.993 B.t.u. Since .49 c.c. gasoline is

\[ \frac{14.993}{.49} = 30.600 \text{ B.t.u. per c.c.} \]

This result was calculated in different units and found to have the value of

40.65 B.t.u. per gram or

18,455.1 B.t.u. per pound.

Derivation of Overall Efficiency Formulae.

The three units in a Delco Plant allow a great variation of the conditions under which the plant may be tested. That is, power may be obtained in three general ways; first, from the generator directly without the battery attached to the line; second, from the battery directly without the generator being attached to the line; and third, from the generator
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with the battery across the line. The last method may be sub-divided into three parts; first, when the battery voltage is higher than the generator terminal voltage, and the battery is supplying energy to help the generator carry the load; second, when the battery voltage is equal to the generator terminal voltage, and is neither supplying nor taking energy; and third, when the battery voltage is lower than the generator terminal voltage, and is taking energy from the generator, so that the latter must charge the storage battery as well as carry the external load. Aside from the above methods of delivering power, there are also several conditions under which the gas engine may be operated. For example; the fuels may be varied in composition from kerosene to gasoline; the back pressure on the exhaust line might be varied to extreme conditions; the conditions of cooling
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might be varied. In fact innumerable conditions could be cited.

But since a discussion of the overall efficiency under each of the above conditions of operating and delivering would in itself make necessary a very lengthy article, it will be the purpose of the following pages to discuss the results of a test made on the Delco Light Plant at various conditions of the battery from zero per-cent charge, with gasoline as the fuel, with the gas engine running under normal operating conditions, with the generator supplying all the energy and the battery floating across the line, neither supplying nor taking energy from the system.

Where a gas engine is involved, there are two efficiencies which must be taken into consideration in determining the overall efficiency. The first is the mechanical efficien-
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cy, the second, the thermodynamic or thermal efficiency. The former is the ratio of the delivered horse-power to the net indicated horse-power as obtained from an indicator card. It may be written

\[
\text{Mechanical Efficiency} = \frac{D.\text{h}.p.}{I.\text{h}.p.} \tag{1}
\]

where D.h.p. is the delivered horse-power, and I.h.p. is the indicated horse-power.

This efficiency is a measure of the power lost due to the mechanical friction of the motor, and of the power required to force the charge into the cylinder. It is the true efficiency of the gas engine with respect to its mechanical operation. However, since this efficiency is not a measure of the various other losses in a gas engine, it cannot be used alone. The thermal efficiency is, however, a measure of the losses not taken care of by the mechanical efficiency.
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This efficiency may be stated as the ratio of the mechanical energy delivered to the piston, to the heat energy liberated by the combustion of the fuel. The mechanical energy delivered to the piston is the I.h.p. of equation (1). The heat energy liberated by the combustion of the fuel is the horse-power second equivalent to one horse-power second, the thermal efficiency formula may be written

\[ \text{Thermal Efficiency} = \frac{0.7069 \times t \times \text{I.h.p.}}{H} \]  

where \( H \) is the B.t.u. input, \( t \) is the time in seconds of combustion, and I.h.p. is the indicated horse-power as obtained from an indicator card.

From the above it is seen, that to obtain the overall efficiency, the entire engine losses, or the losses measured by both the mechanical and thermal efficiencies, must be taken into account. Thus the entire engine
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Losses may be grouped together and measured by what would be called the engine efficiency. By multiplying equations (1) and (2) together, the result will be

\[
\text{Engine Efficiency} = \frac{7069 \times t \times \text{l.n.p.}}{h} \times \frac{\text{D.h.p.}}{\text{l.n.p.}}
\]

or

\[
\text{Engine Efficiency} = \frac{7069 \times t \times \text{D.h.p.}}{h} \quad \ldots (3)
\]

The efficiency of the generator and switchboard may be derived from the equation that efficiency, in general, is equal to output over input. It is then expressed

\[
\text{Generator & Switchboard Eff.} = \frac{VI}{746 \times \text{D.h.p.}}
\]

where \( V \) is the terminal voltage at the switchboard, \( I \) is the line current.

The overall efficiency, which in words, is the ratio of the plant output to the plant input, is therefore equal to the product of engine efficiency times generator and switch-
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board efficiency. Thus, by multiplying together equations (3) and (4), the result is

Overall Efficiency = \frac{0.00948tVI}{H} \quad \ldots \ldots \ldots (5)

Since, from the data sheet No. 2, there are 40.65 B.t.u. per gram of gasoline, then the input in B.t.u. per run was

\[ E = 40.65G \]

where G is the weight in grams of gas used per run.

If \( W_x \), watts output, is substituted for VI, then equation (5) reduces to

Overall Efficiency = \frac{23.3tW_x}{G} \times 10^{-6} \quad \ldots \ldots \ldots (6)

where \( W_x \), t, and G have the same values as before.

General Arrangement of Plant and Apparatus for Testing.

The plant was bolted to a hard wood base 15 inches high. This base was fastened to a girder underneath the floor by means of four
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$\frac{3}{4}$ inch bolts 40 inches long. These extended through the base, through the floor, and bolted to two 2x4 inch cross pieces on the under side of the girder. This base proved to be an exceptionally solid foundation for the plant.

The exhaust line consisted of a 2 and a 4 ft. length of 1 inch pipe, connected by means of a 45 degree elbow to the muffler. This may be seen in the figure on page 24.

In looking over equation (6), and the method of deriving it, it was found that four quantities had to be measured in each run. They are as follows:

A. - Time in seconds.
B. - Weight of gasoline per run.
C. - Voltage across generator.
D. - Line Current.

For measuring the time, a stop watch which measured to fractions of a second was used. A 4-inch Fairbank equal arm balance was
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employed in weighing the gasoline. The gasoline was contained in a quart can with an opening at the top. Through this opening, without touching the sides of the container, the gasoline projected to about \( \frac{4}{4} \) inch from the bottom. The balance and gas container may be seen on page 24, as set up for a test. To minimize the vibration, the balance was placed on a 3 inch felt pad; \( \frac{1}{4} \) inch felt pads were also placed on the balance pans. A piece of \#8 B. and S. gauge copper wire was attached to the right hand balance pan, so that when a balance was obtained, the end of the copper wire just touched the top of the mercury in a mercury cup. This closed a circuit through the frame of the balance, a storage battery, and a buzzer; and gave indication of a balance.

The remainder of the factors necessary in equation (6), the measurement of current and
voltage, may best be explained by reference to figure 11. It is seen that the battery was floating on the line. There was an ammeter in the battery circuit; this was kept at zero throughout all runs. As the battery was brought to a fixed point of charge before each run, current could not be taken from it for starting the engine; an external source, therefore, had to be used. This consisted of the drop over a load box, which was in series with a lamp-rack across a 110 volt circuit; the drop over the load box, when no circuit was being taken by the generator, was about 40 volts.

The view of the apparatus, as set up, is shown on page 24.

Procedure in Determination of Overall Efficiency.

In making a run with the scheme shown in figure 11, the procedure was as follows:
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The battery was run several times through a cycle of complete charge and discharge at the normal rate of 20 amperes. Then the battery was charged to full charge and the run started. The battery was discharged until the amper-hour meter in the battery circuit indicated a certain per-cent charge in the battery. Now the battery was taken off the load and allowed to recuperate for five minutes. Meanwhile, the generator was started from the external source and allowed to heat up for the same period of five minutes. After being heated up, the gas engine was stopped and the gasoline container filled with gasoline. The engine was again started from the external source, and the external load thrown onto the generator. The battery was then thrown across the line, and floated so that it neither received nor delivered power. This "pure" floating was accomplished
TEST OF A DELCO LIGHTING PLANT.

by varying the number of lamps in the external load. When steady conditions were reached, the gasoline container was balanced and then a 2 gram weight taken off. When 2 grams of gasoline were consumed, a balance would be indicated by the buzzer; at this time the stop watch was started. A 50 gram weight was now taken off, and the stop watch let run until the buzzer indicated a balance again. This gave the time required to consume 50 grams. During the run, readings were taken of the specific gravity of eight cells, and an average of these made. Readings were also taken of the following instruments: ampere-hour meter, ammeter, voltmeter and tachometer. The above set of operations completed the run for this condition of the battery. Runs similar to the above were made with the battery at various points of charge, ranging from full charge to zero charge. Check runs
TEST OF A DELCO LIGHTING PLANT.

were taken at all points throughout the test. The data taken is shown in data sheet #3.

Difficulties Encountered in the Test.

Before obtaining the final results, several difficulties were encountered. One of these was due to the fact that a run was made immediately after discharging the battery; as no time was given for the battery to recuperate from polarization effects, the battery voltage rose during the run, thereby affected the results. After this error was noted, the battery was allowed to stand about ten minutes after discharge, during which time the engine was warmed up.

A great deal of trouble was experienced in obtaining the gasoline consumption accurately, due to the excessive vibration of the scales. This was remedied by placing alternate layers of felt and rubber padding to a thickness of 3
Data Sheet No. 3.

Overall Efficiency of Delco Lighting Plant.

<table>
<thead>
<tr>
<th>Iₜ</th>
<th>V</th>
<th>Time R.p.m.</th>
<th>Wₓ</th>
<th>Eff.</th>
<th>Kw-hr.</th>
<th>Amp.-hr.</th>
<th>Output</th>
<th>Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.7</td>
<td>33.7</td>
<td>264.7</td>
<td>1000</td>
<td>799</td>
<td>9.85</td>
<td>0.0587</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>23.6</td>
<td>33.6</td>
<td>247.5</td>
<td>1005</td>
<td>800</td>
<td>9.23</td>
<td>0.0549</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>24.7</td>
<td>32.5</td>
<td>252.0</td>
<td>1030</td>
<td>803</td>
<td>9.45</td>
<td>0.0562</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>24.8</td>
<td>32.2</td>
<td>252.6</td>
<td>1025</td>
<td>805</td>
<td>9.50</td>
<td>0.0566</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>24.6</td>
<td>32.2</td>
<td>259.2</td>
<td>1010</td>
<td>795</td>
<td>9.32</td>
<td>0.0565</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>24.5</td>
<td>32.8</td>
<td>248.0</td>
<td>1010</td>
<td>802</td>
<td>9.19</td>
<td>0.0545</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>25.8</td>
<td>31.5</td>
<td>237.1</td>
<td>1025</td>
<td>812</td>
<td>9.21</td>
<td>0.0536</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>25.4</td>
<td>31.6</td>
<td>254.8</td>
<td>1025</td>
<td>810</td>
<td>8.85</td>
<td>0.0526</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>26.7</td>
<td>30.8</td>
<td>228.8</td>
<td>1050</td>
<td>823</td>
<td>8.60</td>
<td>0.0523</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>25.5</td>
<td>30.9</td>
<td>241.1</td>
<td>1040</td>
<td>789</td>
<td>8.90</td>
<td>0.0526</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>27.7</td>
<td>28.3</td>
<td>218.5</td>
<td>1120</td>
<td>784</td>
<td>8.00</td>
<td>0.0477</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>27.2</td>
<td>28.6</td>
<td>228.1</td>
<td>1080</td>
<td>778</td>
<td>8.30</td>
<td>0.0493</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>29.2</td>
<td>25.3</td>
<td>214.2</td>
<td>1155</td>
<td>736</td>
<td>7.36</td>
<td>0.0438</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>27.6</td>
<td>27.0</td>
<td>222.1</td>
<td>1115</td>
<td>750</td>
<td>7.78</td>
<td>0.0462</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

50 grams gas used in all runs.

Instruments used

Iₜ-#2098 V-#1155 Stop Watch #2

Tachometer #29943.
Data Sheet No. 4.

Overall Efficiency of Delco Light Plant.

| % Charge of R.p.m. | Av. Spec. Eff. | Av. Kw-hr. per Gal. Cents Kw-hr. per Kw-hr. |
|-------------------|----------------|-------------------------------------------|-------------------------------------------|
| Battery           | Av. Grav.      | Output                                   | Gal. Kw-hr.                              | per                           |
| 0                 | 1.135          | 1.171                                     | 7.57                                     | .0450                         | .389                         | 7.44                         |
| 12                | 1.100          | 1.177                                     | 8.15                                     | .0485                         | .361                         | 6.91                         |
| 36                | 1.045          | 1.183                                     | 8.95                                     | .0525                         | .333                         | 6.37                         |
| 43                | 1.025          | 1.192                                     | 9.03                                     | .0532                         | .329                         | 6.25                         |
| 64                | 1.010          | 1.202                                     | 9.40                                     | .0555                         | .316                         | 6.04                         |
| 84                | 1.027          | 1.211                                     | 9.48                                     | .0564                         | .310                         | 5.89                         |
| 100               | 1.002          | 1.218                                     | 9.54                                     | .0568                         | .308                         | 5.85                         |

Cost of gasoline assumed at 19 cents per gallon.
TEST OF A DELCO LIGHTING PLANT.

Because more than one run was made before refilling the gasoline container, it was found that the gasoline did not feed properly, due to a change in the level of the gasoline. This was found to affect the efficiency results, so that consistent results could not be obtained with the two different levels. Filling the container before each run obviated this difficulty.

Calculation of data.

Using equation (6), the overall efficiency was calculated from the tabulated data in sheet #3. As 50 grams was the constant weight of gasoline used in each run, equation (6) may be reduced to the following form:

\[ \text{Overall Efficiency} = \frac{4.077W_x}{10^{-6}} \ldots (7) \]

By substituting in equation (7), the efficiency is obtained directly. For instance,
TEST OF A DELCO LIGHTING PLANT.

when the time was 264.7 seconds and the watts output was 799 watts, the efficiency, using equation (7), was:

\[
\text{Eff.} = 0.467 \times 264.7 \times 799 \times 10^{-6} = 0.0985 = 9.85\%
\]

A calculation was also made of the kilowatt-hour output per gallon, and of the gallons per kilowatt-hour output. To find this, the 50 grams input were changed to gallons. As the specific gravity of the gasoline used was .7527, 50 grams are equal to

\[
\frac{50}{.7527} = 66.4 \text{ c.c.} = 0.01752 \text{ gallons.}
\]

To obtain the kilowatt-hour output, the watt-seconds were divided by \(3600 \times 1000\).

From this, the kilowatt-hour output was expressed as

\[
\text{kw-hr.} = \frac{2775\text{w} \times 10^{-5}}{.01752} \quad \cdots \quad (8)
\]

As this output was produced by .01752 gallons, then one gallon produced

\[
\text{kw-hr. per gallon} = \frac{\text{kw-hr. per run}}{.01752} \quad \cdots \quad (9)
\]
TEST OF A DELCO LIGHTING PLANT.

Substituting in equations (8) and (9), the kilowatt-hours per run and per gallon was obtained immediately. If, for example, the time was 264.7 seconds, and the watts output were 799 watts, the kilowatt-hours per run were from equation (8),

\[ 0.2775 \times 264.7 \times 799 \times 10^{-6} = 0.0557 \text{ Gal. per run.} \]

From equation (9), the Kw-hr. per gallon were

\[ \frac{0.0557}{0.1752} = 3.325 \text{ Kw-hr. per gallon.} \]

The gallons per Kw-hr. were the reciprocal of the above were equal to

\[ \frac{1}{3.325} = 0.3005 \text{ gallon per Kw-hr.} \]

To obtain cost figures, a cost of gasoline per gallon had to be assumed; this was chosen at 19 cents per gallon. Now by obtaining the product of gallons per Kw-hr. and cost per gallon, it is apparent that the result is cost per Kw-hr. An example of this may be taken when the gallons per Kw-hr. were .1760. The cost per Kw-hr. was
TEST OF A DELCO LIGHTING PLANT.

then found to be

\[ 0.3005 \times 19 = 5.71 \text{ cents per Kw-hr.} \]

Discussion of Results.

After all the data was calculated in the above manner, the results were tabulated in data sheet #3. To obtain a graphical representation of the data, a set of curves, see page 53, were drawn with the per-cent charge of the battery as the independent variable. These curves show how the specific gravity, the generator voltage, the speed, the efficiency, and the cost vary with the per-cent charge of the battery.

It should be noticed that the voltage curve is very flat between 40 and 65 per-cent charge, whereas, below 40 per-cent charge the voltage decreases very rapidly, and above 65 per-cent charge, the voltage increases very rapidly per unit change in charge. The per-
TEST OF A DELCO LIGHTING PLANT.

Cent variation in battery voltage between the limits of 40 per-cent and 85 per-cent charge may be expressed as

$$\frac{32.5 - 31.5}{31.5} = 0.0317 = 3.17\%.$$  

The variation in speed was from 1135 R.p.m. at zero per-cent charge to 1002 R.p.m. at 100 per-cent charge. This decrease of speed with an increase of the per-cent charge, was due to the fact that the load increased as the per-cent charge increased.

The cost and efficiency curves indicate that the most efficient point of operation of the engine and generator is when the battery is at 100 per-cent charge. At this point the efficiency was a maximum of 9.54 per-cent and the cost a minimum of 5.85 cents per Kw-hr. output. From about 50 per-cent charge to 100 per-cent charge, the efficiency and cost curves are nearly flat and have values of 9.47 per-cent for the
TEST OF A DELCO LIGHTING PLANT.

efficiency curve and 5.95 cents per Kw-hr. for the cost curve.
Part 3.

The Methods Used and Results Obtained in Approximating Several of the Losses in the Outfit; and the Auxiliary Tests necessary in determining these Losses.
DELCO-LIGHT

Cross-Section of Delco-Light Plant.
TEST OF A DELCO LIGHTING PLANT.

Key to Part 3.

$I_a$ - Armature Current.
$I_f$ - Field Current.
$I_l$ - Line Current.
$R_{a+b}$ - Resistance of Armature and Brushes.
$R_f$ - Resistance of Field.
$V_a$ - Armature Voltage.
$V$ - Line Voltage.
$P_s$ - Stray Load Loss.
TEST OF A DELCO LIGHTING PLANT.

Calibration of the Generator for use as a Motor.

In the determination of the losses, as described in the following pages, the calibrated motor method was used.

When calibrated as a motor, everything was removed from the crank shaft. The only power supplied to the motor was that necessary to overcome electrical losses and friction and windage losses. These may be divided into two groups.

(a) The copper losses.
(b) The stray load losses.

The copper losses are subdivided into two parts, an armature loss and a field loss; these may be expressed as

arm. copper loss = IaRatb,

field copper loss = Iff

where I is the armature current, If the shunt field current, Ratb the resistance of the
armature and brushes, and \( R_f \) the resistance of the field.

The stray load loss consists of the hysteresis and eddy current losses, and the friction and windage losses. As the latter losses are dependable upon the speed of the machine, they will be constant for a given speed. The hysteresis and eddy current losses will vary with both the speed and the voltage of the machine.

In determining the stray load loss, the field circuit was opened, and an ammeter and rheostat inserted as shown in Fig. 12. This figure also shows the means of applying a variable voltage across the armature.

The procedure was that outlined in the A.I.E.E. standardization rules, and is in brief as follows: The speed was kept constant at 1000 R.p.m. by means of the field
Calibration of Generator as a Shunt Motor.

Figure 12.
TEST OF A DELCO LIGHTING PLANT.

rheostat, and readings were taken of instruments at various voltages, from a maximum of 70 volts to a minimum of 18 volts. The results were tabulated in data sheet No. 6.

The stray load, as shown in this data sheet, was equal to total input minus the copper losses. To obtain the copper losses, reference was made to values of resistances given in the curves on page 62. The curve obtained from data sheet No. 6 is shown on page 64.

Determination of the Friction and Windage Losses.

It was desired to secure an idea of the relative values of the losses due to friction, windage, and compression in the engine. The most simple method, which presented itself for the determination of the above losses, was that of the calibrated
Data Sheet No. 5.

Calculation of Resistance of Armature and Field of Generator.

Temperature of Field at 100°F.

<table>
<thead>
<tr>
<th>Voltmeter Across Switchboard Terminals.</th>
<th>Field.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. I 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 30.0</td>
<td>0.96</td>
</tr>
<tr>
<td>Av. V 1.55 2.31 3.11 3.80 4.51 5.22 5.94 6.61 7.32 8.70</td>
<td>32.6</td>
</tr>
<tr>
<td>Res. .310 .308 .311 .304 .300 .298 .297 .294 .292 .290</td>
<td></td>
</tr>
</tbody>
</table>

Voltmeter Across Brushes. (Armature & Brush)

<table>
<thead>
<tr>
<th>Voltage Across Armature.</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Av. I 2.5 5.0 7.5 10.0 12.5 15.0 20.0 25.0</td>
<td>3.4</td>
</tr>
<tr>
<td>Av. V .67 1.35 2.00 2.67 3.28 3.98 5.28 6.54</td>
<td></td>
</tr>
<tr>
<td>Res. .268 .270 .267 .267 .265 .264 .262</td>
<td></td>
</tr>
</tbody>
</table>

Res. .200 .208 .211 .213 .218 .223 .230 .239
**Data Sheet No. 6.**

**Stray Load Loss.**

<table>
<thead>
<tr>
<th>V</th>
<th>70</th>
<th>65</th>
<th>58.2</th>
<th>34.7</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>If</td>
<td>1.95</td>
<td>1.74</td>
<td>1.25</td>
<td>0.45</td>
<td>0.0</td>
</tr>
<tr>
<td>Itot</td>
<td>5.5</td>
<td>5.42</td>
<td>5.05</td>
<td>5.60</td>
<td>22.5</td>
</tr>
<tr>
<td>Ia</td>
<td>3.55</td>
<td>3.68</td>
<td>3.80</td>
<td>5.15</td>
<td>22.5</td>
</tr>
<tr>
<td>Ea</td>
<td>0.311</td>
<td>0.311</td>
<td>0.310</td>
<td>0.310</td>
<td>0.295</td>
</tr>
<tr>
<td>Ia/Ra</td>
<td>1.105</td>
<td>1.145</td>
<td>1.180</td>
<td>1.600</td>
<td>6.630</td>
</tr>
<tr>
<td>Ec</td>
<td>68.89</td>
<td>63.85</td>
<td>57.02</td>
<td>33.10</td>
<td>11.37</td>
</tr>
<tr>
<td>Ec/La</td>
<td>244.</td>
<td>235</td>
<td>217</td>
<td>171</td>
<td>256</td>
</tr>
</tbody>
</table>
Graph of a Delayed Light Flare

ETHYLFERA LILDE

T. L. Zeller

R. H. Dugan

General Institute of Technology
TEST OF A DELCO LIGHTING PLANT.

It was decided to obtain the data for most of these losses before the generator was calibrated as a motor, as this calibration would require the tearing down of the plant. The objection to calibrating first, lay in the fact that if the machine were once torn down, on reassembly the friction of some of the parts would, in all probability, be changed due to the machine requiring a "breaking in" once more.

Fig. 13 shows the arrangement of the motor connections which were used. As will be noted, only the shunt field of the motor was used; the short circuiting of the series field was adhered to throughout all the tests made. An ammeter A was placed in the shunt field circuit; this was accomplished by removing one side of the shunt field from the
Using the Generator as a Shunt Motor to Drive the Gas Engine.

Figure 13.
TEST OF A DELCO LIGHTING PLANT.

armature connection and bringing leads outside the machine to the ammeter. The voltmeter was placed across the terminals of the switchboard (a correction was made in the calculations for the drop in the switchboard). An ammeter A was used to measure the total current supplied to the motor.

In order to drive the engine at rated speed, 1000 R.p.m., the voltage impressed across the motor had to be far above that which could be supplied by the battery; therefore, an external source of current had to be resorted to a 110 volt source was used, and a lamp rack was placed in series with this as shown in the figure. By means of varying the number of lamps in circuit in the lamp rack, a wide range of voltage could be obtained across the motor.

The first loss which was determined
TEIT OF A DELCO LIGHTIN G PLANT.

was that due to the power required to circu- culate the cooling air through the machine. This was accomplished as follows: The en- gine was run by its own fuel in the regular way until at normal operating temperature. The gas line was then disconnected and the engine driven by the motor at 1000 F.p.m., the input to the motor was recorded. The flywheel was next removed from the engine, and the openings of the vanes were blocked. This blocking was done by glueing long strips of heavy drawing paper about the periphery of the flywheel, and then binding this securely to the flywheel by means of heavy twine. This proved a very effective manner of blocking the flywheel openings, as was shown by the fact that when the engine was run, a piece of tissue paper placed before the air intakes showed no tendency to be
TEST OF A DELCO LIGHTING PLANT.

sucked in. The engine was run until it reached normal temperature again. The gas line was quickly disconnected, and the engine driven by the motor. The input to the motor was recorded. Now, since the outputs of the motor were equivalent to the powers required to draw the engine, the difference of the output first with the engine in normal condition, and then with the vanes blocked, gave the power required to circulate the air through the generator and engine.

The next observation was made with the flywheel removed. The difference between the output of the motor for the preceding case and the output of the motor for the new condition, was the bearing friction and windage due to the flywheel. The windage here is aside from that due to the pumping action of the flywheel.
TEST OF A DELCO LIGHTING PLANT.

On removing the piston from the crankshaft, it was found that the crankshaft could not be driven safely without removing the piston from the cylinder. The simplest way of doing this required the cylinder to be removed, so it was decided to entirely disassemble the machine, and then place each part back on and measure as many losses as it was possible to observe.

While the machine was in this disassembled condition, the runs for calibrating the generator as a motor were made.

The machine as it now stood had only the crankshaft and armature in place. It was warmed up by running the motor. The input to the motor was measured. The complete valve mechanism was now placed on the machine (this necessitated placing the cylinder and head on) and the input to the motor measured once more.
TEST OF A DELCO LIGHTING PLANT.

It was found, though rather surprising, that the input required to operate the machine when the whole valve mechanism was in place, was less than that required when the cylinder was removed together with the valve mechanism. It was decided that the inconsistency of the results lay in the fact that the increased vibration in the case where the engine was completely dismantled accounted for a greater input here than was required when engine was partially built up. Although there undoubtedly was a greater friction and operating loss in the latter than in the former case, the loss due to vibration far overshadowed this.

When the push rods were removed from their pistons and a run made, it was found here also, that less input was required with the push rods in place operating the valves.
TEST OF A DELCO LIGHTING PLANT.

then with the push rods removed. The actual difference in power was calculated to be 16.0 watts in the wrong direction, so to speak. This figure could be considered to be made up of the algebraic sum of the radiation in loss due to the rods being removed, which is of one sign, and the vibration losses which follow this removal, which are of opposite side.

The machine was again completely assembled, and the engine run until t normal temperature. The spark plug was quickly removed, and the engine driven by the generator; the input to the generator, which was being driven as a motor, was measured. The outfit was run again in the normal manner until t normal temperature; then driven by the motor generator, and the input noted. (It will be noticed that this input, which corresponds to the input required to drive the engine
Data Sheet No. 7.

Data for Flywheel and Compression Losses in the Engine.

1000 R.p.m.  Outfit at normal temp.

<table>
<thead>
<tr>
<th>Description</th>
<th>Av. V</th>
<th>Av. I</th>
<th>**Col.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outfit complete</td>
<td>67</td>
<td>10.36</td>
<td>A</td>
</tr>
<tr>
<td>Flywheel openings stopped</td>
<td>66.75</td>
<td>9.25</td>
<td>B</td>
</tr>
<tr>
<td>Flywheel removed</td>
<td>66.37</td>
<td>9.06</td>
<td>C</td>
</tr>
<tr>
<td>*Outfit complete</td>
<td>66</td>
<td>10.36</td>
<td>D</td>
</tr>
<tr>
<td>*Outfit complete without compression</td>
<td>65.3</td>
<td>7.91</td>
<td>E</td>
</tr>
</tbody>
</table>

**Columns in following calculation sheet.

*After reassembling.
Data Sheet No. 8.

Calculation of Motor Outputs to Find the Value of Engine Losses.

<table>
<thead>
<tr>
<th>Outfit</th>
<th>Flywheel complete openings stopped.</th>
<th>Flywheel complete moved.</th>
<th>Outfit Outfit Com- (re- out com- assembled.) pressed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column</td>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td>Av. V.</td>
<td>67</td>
<td>66.75</td>
<td>66.37</td>
</tr>
<tr>
<td>Av. Itot.</td>
<td>10.38</td>
<td>9.25</td>
<td>9.06</td>
</tr>
<tr>
<td>Rb-a-b</td>
<td>0.266</td>
<td>0.267</td>
<td>0.267</td>
</tr>
<tr>
<td>Rs-w.</td>
<td>0.040</td>
<td>0.042</td>
<td>0.040</td>
</tr>
<tr>
<td>IR-s-w.</td>
<td>0.415</td>
<td>0.37</td>
<td>0.36</td>
</tr>
<tr>
<td>Vs</td>
<td>66.59</td>
<td>66.38</td>
<td>66.01</td>
</tr>
<tr>
<td>If</td>
<td>1.96</td>
<td>1.955</td>
<td>1.941</td>
</tr>
<tr>
<td>Ia</td>
<td>8.42</td>
<td>7.295</td>
<td>7.12</td>
</tr>
<tr>
<td>Ia-Ra-b</td>
<td>2.24</td>
<td>1.94</td>
<td>1.89</td>
</tr>
<tr>
<td>Ec</td>
<td>64.35</td>
<td>64.44</td>
<td>64.12</td>
</tr>
<tr>
<td>Ps</td>
<td>234.</td>
<td>234.3</td>
<td>233.75</td>
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<tr>
<td>2IaRa-b</td>
<td>18.85</td>
<td>14.35</td>
<td>13.52</td>
</tr>
<tr>
<td>2IaRa-b-Ps</td>
<td>252.6</td>
<td>248.6</td>
<td>247.3</td>
</tr>
<tr>
<td>IaVa</td>
<td>552.</td>
<td>484.</td>
<td>460.</td>
</tr>
<tr>
<td>Output</td>
<td>299.2</td>
<td>235.4</td>
<td>212.3</td>
</tr>
</tbody>
</table>
Data Sheet No. 9.

Flywheel and Compression Losses in Engine.

Loss due to air circulating action of flywheel = output column A - output column B of preceding sheet - 63.9 watts.

Frictional loss due to flywheel =

B - C - 23. Watts.

Approx. loss due to cylinder compression = D - E - 148.5 Watts.
TEST OF A DELCO LIGHTING PLANT.

complete, is slightly greater after the re-
assembly than before disassembly. This was
probably due to the increase in friction in
the second case, due to the parts not being
well "worked in" in their new positions.
The difference between the outputs of the
motor generator, when complete, and with the
spark plug removed, give an idea of the loss
due to compression.

The Determination of the Heat Carried Away
by the Cooling Air.

The anemometer method was used in
calculating the heat carried away by the cool-
ing air. The anemometer used was calibrated
on a 23.5 ft. revolving arm; the resulting
calibration curve is shown on page 80.

In order to accurately measure the
amount of air flowing, projections had to be
built on the two intakes, that of the motor
TEST OF A DELCO LIGHTING PLANT.

and of the engine. These are shown in the figure on page 76. The projecting intakes were made of heavy paper; the engine intake was cylindrical, being 12.75 inches long and 6.63 inches in diameter. It was glued over the top of the engine intake in such a way as to fit very tightly. The generator inlet was conical in shape, being in the shape of the frustrum of a cone with a lower base diameter of 9 inches, an upper base or inlet of diameter 4.666 inches, and an attitude of 21 inches. This frustrum was glued securely to the generator inlet.

The plant was run until the temperatures of the inlet air and exhaust air was constant. It will be seen from the data, that there is a difference in the temperatures of the engine inlet and generator inlet. This was partly due to the position of a lighted lamp rack near the
Heat in Cooling Air of Dolco-Light Plant.
Data Sheet No. 10.

Calibration of Anemometer #1751.

<table>
<thead>
<tr>
<th>Indicated Reading</th>
<th>0.6 3.9 7.5 11.0 18.6 22.6 28.3</th>
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</thead>
<tbody>
<tr>
<td>True Reading</td>
<td>1.4 4.0 7.0 10.0 16.5 19.8 24.5</td>
</tr>
</tbody>
</table>
Test of a Delco Light P type
CALIBRATION CURVE of ANEMOMETER #A/751
Thesis 1919 Course E.E.
L. E. Given E. D. Forges
Armour Institute of Technology
Data Sheet No. 11.

Calculation of Heat Given to Cooling Air.

Av.
Gen. inlet temp. in deg. F. 70.9
Eng. inlet temp. in deg. F. 76.9
Flywheel exit temp. in deg. F. 104.0
R.p.m. 1000.

Duration of run in sec. 300
Anemometer at gen. inlet. 3150.
Anemometer at eng. inlet. 6060.
Av. dia. of gen. inlet open. 4.686
Av. dia. of eng. inlet open. 6.625
Barometer reading in inches Hg. 29.36

% humidity. 43.25
Sp. heat of air under op. cond. 0.2374
Density of air under op. conditions. 0.001265

Observed velocity in ft. per sec. at gen. inlet. 10.5
Observed velocity in ft. per sec. at eng. inlet. 20.2
Corrected velocity in ft. per sec. at gen. inlet. 9.5
Corrected velocity in ft. per sec. at gen. inlet. 17.9
Area of opening at gen. inlet in sq. inches. 17.48
Area of opening at eng. inlet in sq. inches. 30.70

Wt. in lbs. per sec. of gen. inlet air. 0.901
Wt. in lbs. per sec. of eng. inlet air. 0.302
Rise in temp. of gen. cooling air in deg. F. 33.1
Rise in temp. of eng. cooling air in deg. F. 27.1
B.t.u. per Sec. to gen. cooling air. 0.786
B.t.u. per Sec. to eng. cooling air. 1.942
Watts to gen. cooling air. 629
Watts to eng. cooling air. 2050
Total watts loss in cooling air. 2879
TEST OF A DELCO LIGHTING PLANT.

machine; but since those inlet temperatures remained constant, this difference did not affect the results obtained.

Several five minute runs were made with the anemometer alternately in the generator and engine inlets; the results of these are shown in the data sheet No. 11.

The density of the air corresponding to the pressure and humidity conditions existing was calculated. Knowing the specific heat of the air, the rise in temperature through the machine, and the weight of air passing through per second, the watts loss due to the cooling air was calculated.

**Efficiency Determination of the Generator With the Unbalanced Crankshaft.**

It was desired to get the shape of the efficiency curve of the generator.

Since the data for this determination
TEST OF A DELCO LIGHTING PLANT.

could be only obtained with the unbalanced crankshaft revolving, a constant loss was introduced in the input required to overcome the vibration present. Since the speed was kept constant, this had the effect of lowering the whole curve due to a constant loss; but the general shape of the curve was the same as if the vibration had not been present.

The calculation of the efficiency was done according the A.I.E.E. method. The data required, which were the resistances of the armature and field, were taken from data obtained in the calibration of the generator as a motor.

The losses which were calculated were, armature copper loss, field loss, and stray load loss. The stray load loss was taken from the stray load curve of the machine.

The formula for the efficiency which
TEST OF A DELCO LIGHTING PLANT.

was used was

$$\text{Eff.} = \frac{V_{\text{ail}}}{V_{\text{ail}} - V_{\text{ail}} - I_{\text{a}} - I_{\text{a}} - P_{\text{s}}}$$

the symbols of which are given in the key on page 56.
Data Sheet No. 12.

Efficiency of Shunt Generator of Delco-Light Plant.

With Unbalanced Crankshaft.

Speed = 1000 R.p.m. - 7 - V = 33.7 Volts.

<table>
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<tr>
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<th>4</th>
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<th>12</th>
<th>16</th>
<th>20</th>
<th>24</th>
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</thead>
<tbody>
<tr>
<td>I_c</td>
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<td>.332</td>
<td>.528</td>
<td>.705</td>
<td>.882</td>
<td>1.06</td>
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<td>I_rsw</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>V_a</td>
<td>33.52</td>
<td>33.35</td>
<td>33.17</td>
<td>32.99</td>
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<tr>
<td>I_f</td>
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<td>.980</td>
<td>.974</td>
<td>.969</td>
<td>.964</td>
<td>.958</td>
</tr>
<tr>
<td>I_a</td>
<td>4.99</td>
<td>8.98</td>
<td>12.97</td>
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<td>24.96</td>
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<td>5.55</td>
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<td>V_g</td>
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<td>35.73</td>
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<td>38.37</td>
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<tr>
<td>P_s</td>
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<td>179.0</td>
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<tr>
<td>I_aFa</td>
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<td></td>
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</tr>
<tr>
<td>V_a</td>
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<tr>
<td>Input</td>
<td>346.6</td>
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<td>651.6</td>
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<td>1163.2</td>
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<td>Eff</td>
<td>38.6</td>
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<td>61.2</td>
<td>65.0</td>
<td>66.6</td>
<td>67.3</td>
</tr>
</tbody>
</table>

Instruments Used.

V - #1155 I_1 - #2098 I_f - #207.
TEST OF A DELCO LIGHTING PLANT.

Bibliography.

Calorimetry.
    A. Bates.

Electricity for the Farm and Home.
    Frank Koestner.

Electricity on the Farm.
    Frederick Anderson.
TEST OF A DELCO LIGHTING PLANT.

Calculation of Transmission Wire.

To facilitate the calculation of the size of wire needed for a Delco Light installation, the curves on page 90 were drawn. In this set of curves, the abscissae is the quotient of the current to be delivered by the plant, divided by the voltage drop permissible in transmission. The ordinates are the sizes of wire in B. & S. gauge.

For example suppose that the Delco Plant is situated 25 feet from the center of the load, and it is required to deliver 20 amperes with a drop of only 1 volt. By going up the "20" line till the 25 foot curve is reached and then going over to the scale of ordinates, it is seen that No. 10 B. & S. gauge wire must be used. If the permissible drop was $2\frac{1}{2}$ volts, the "8" line would be followed, and it would be noted that No. 14 B. & S. gauge wire should be used.