# EFFICIENCY AND REGULATION

of

# GASOLINE ELECTRIC GENERATOR.

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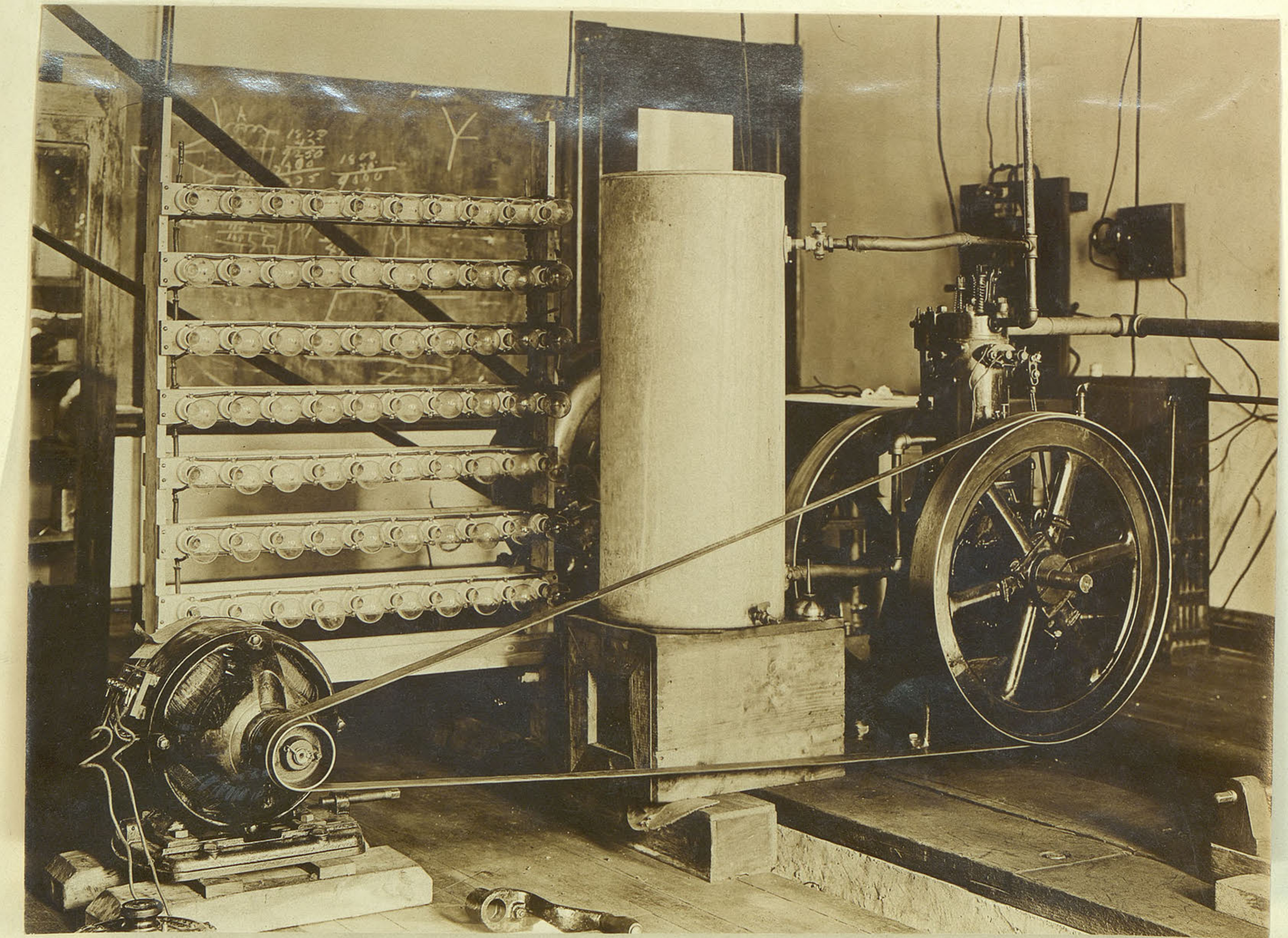
A.D.Stoddard,

Jay L. Dow.

# Outline.



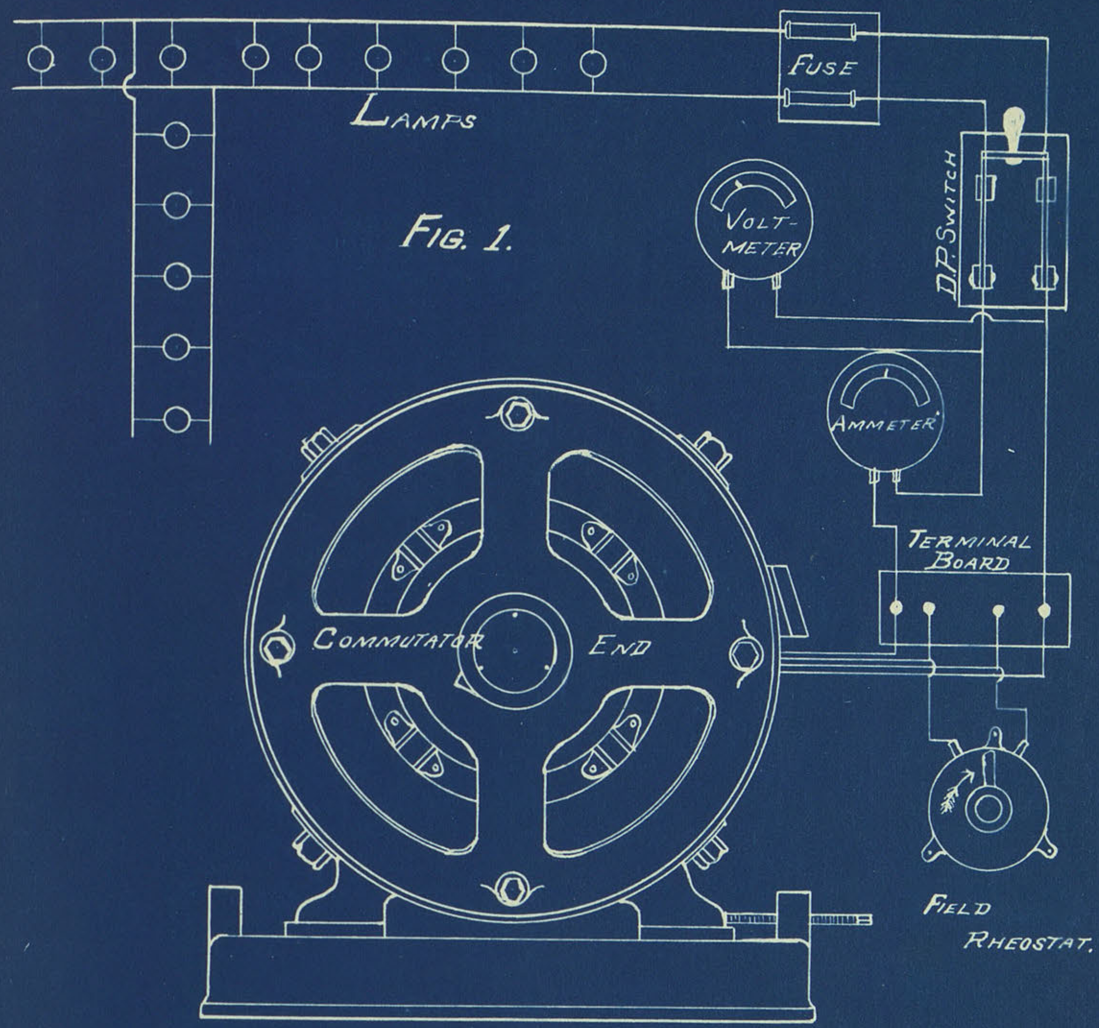

LAMPS
FUSE
VOLT-METER
D.P. SWITCH
AMMETER
TERMINAL BOARD
COMMUTATOR END
FIELD RHEOSTAT.

FIG. 1.

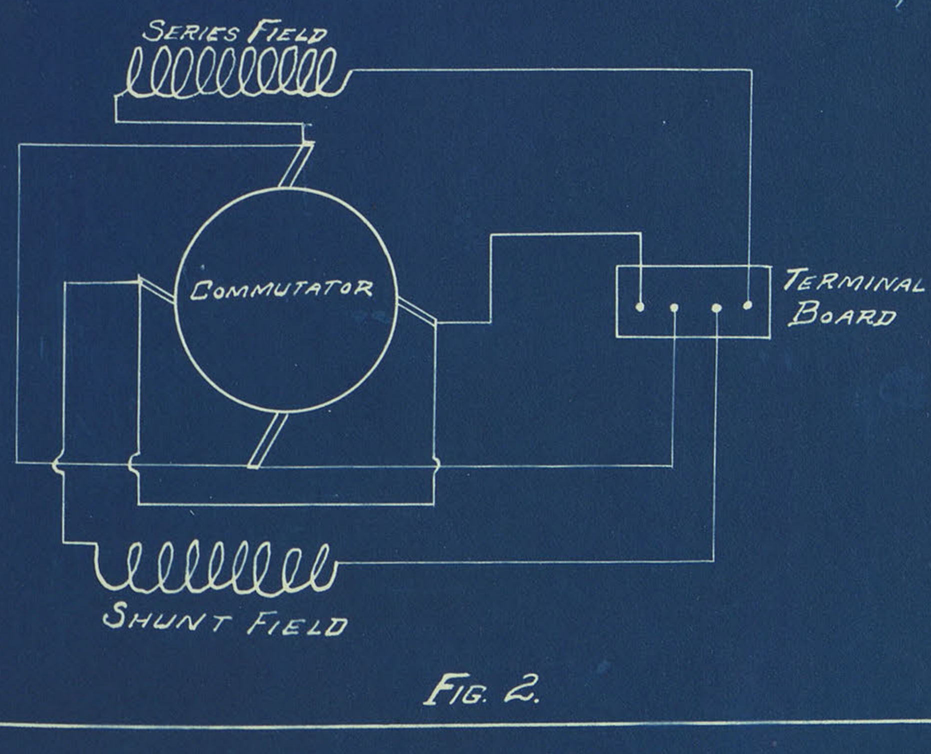

SERIES FIELD
COMMUTATOR
TERMINAL BOARD
SHUNT FIELD

FIG. 2.

# THE DYNAMO.

The dynamo tested is a 1.5 K.W. machine generating 115 volts at a speed of 1850 R.P.M. and is short shunt compound wound. It is constructed so as to require little care, having self oiling ring bearings and brushes that do not require shifting with increase of load. The terminal block on the side of the machine is arranged so simply that no mistake could be made in making the connections.

## External Characteristic.

The curve following shows the external characteristic of the dynamo. In obtaining the data for this curve the dynamo was run at constant speed. The rheostat in the shunt field was adjusted so that a voltmeter placed across the terminals reads 110 volts when the dynamo is running without load. The position of the rheostat arm is not changed during the test.

A variable resistance and an ammeter are placed in the external circuit. The resistance is decreased, thus increasing the load until the limit of the machine is reached. Readings are taken simultaneously of line amperes and terminal volts for a number of intermediate points. This data is plotted with terminal volts as ordinates and line amperes as abscissas.

The object of compounding a dynamo is to maintain a constant voltage at some point on the circuit. The voltage of a shunt dynamo gradually falls as the load increases, therefore in order to maintain a constant potential regulation of the rheostat would be necessary. By compounding the regulation is automatic and no adjustment of the rheostat is necessary.

The series field turns in the compound dynamo may be of such number as to compensate for the machine losses only, maintaining a constant voltage at the terminals of the dynamo, and in addition turns may be added so as to compensate for drop in speed of the dynamo and for line losses. When made to compensate for drop in speed or for line losses the dynamo is said to be over-compounded.

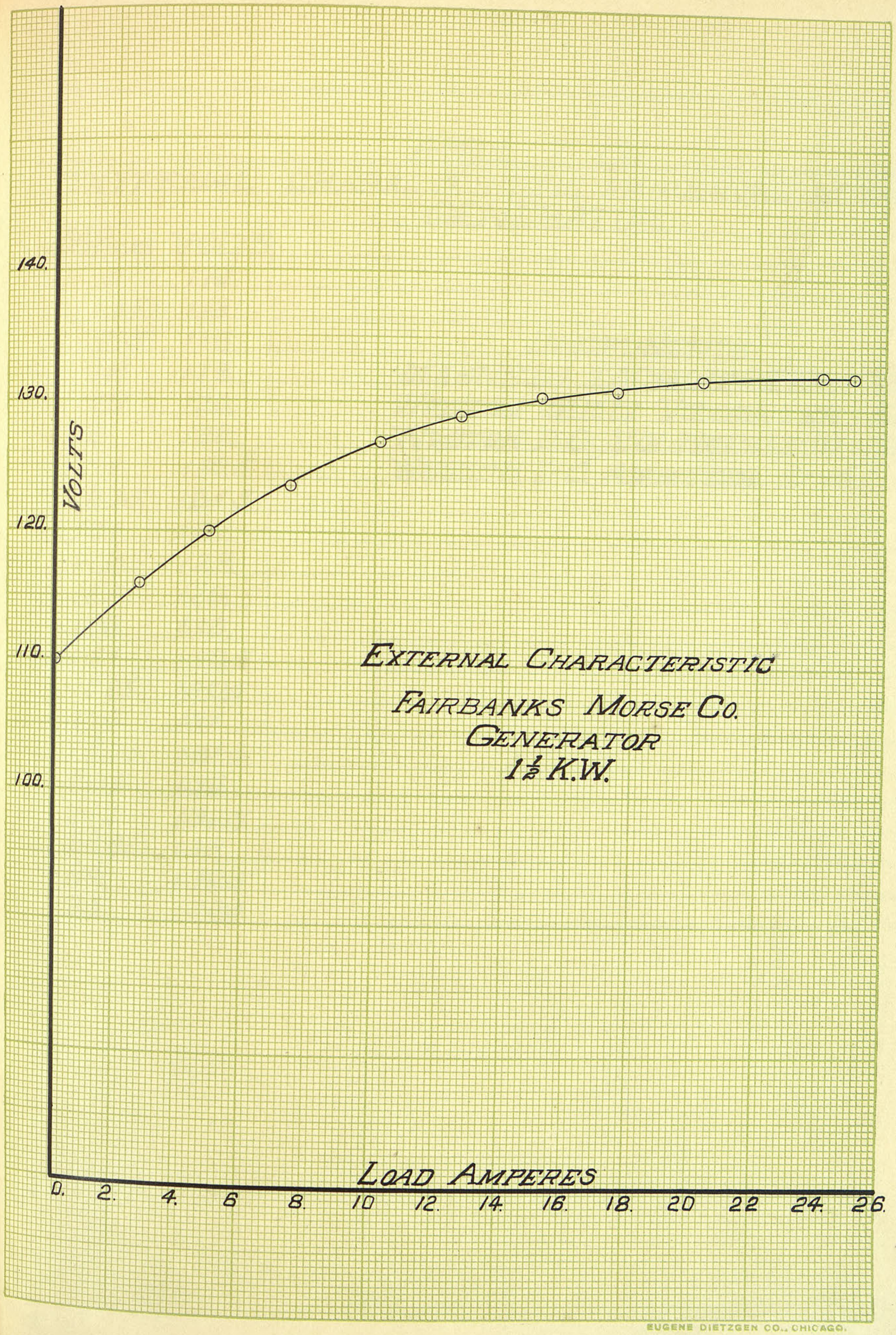
The curve shows that the dynamo is over-compounded, the voltage rising from 110 at no load to 128.5 at full load showing an over-compounding of 16.8%. The speed characteristic of the gasoline engine is such that when the generator is run by the engine a nearly constant voltage will be maintained at the terminals.

## Magnetization Characteristic.

The data for this curve was obtained by connecting the shunt field through an ammeter and rheostats to a source of current. The dynamo is run at constant normal speed. A voltmeter is placed across the terminals of the dynamo. Readings are taken of field current and terminal volts as the former is varied from zero to maximum value. The results are plotted with volts as ordinates and field current as abscissas. As the field current is proportional to the field ampere turns and the voltage is proportional to the flux, the result is a magnetization curve.

The voltage regulation of a generator depends upon the saturation of the various parts of the magnetic circuit. The curve rises for some distance as a nearly straight line, then gradually turns and tends to become parallel to the X axis. That portion where the bend occurs is called the knee of the curve. Generators are usually designed to operate at a point just below the knee of the curve. When so designed a certain amount of increase in excitation produces a known rise in voltage, but owing to saturation of the magnetic circuit it is impossible to raise the voltage far above normal.

As load is placed on a generator, owing to armature reaction and copper drop, the voltage would tend to drop as load is applied if the magnetization were not increased. If the generator at no load is worked too near the knee of the curve a large increase in exciting current will be required to maintain the voltage constant under load.



EUGENE DIETZGEN CO., CHICAGO.

APRIL 7 '06.

EXTERNAL CHARACTERISTIC FAIRBANKS MORSE GENERATOR.

| LOAD AMPERES | VOLTS |
|---|---|
| 0 | 110. |
| 1.75 | 113. |
| 2.75 | 116. |
| 3.6 | 118. |
| 4.9 | 120. |
| 6. | 122. |
| 7.4 | 123.5 |
| 8.75 | 125.5 |
| 10.1 | 127. |
| 11.25 | 128. |
| 12.6 | 129. |
| 13.8 | 130. |
| 15.1 | 130.5 |
| 16.25 | 130.5 |
| 17.5 | 131. |
| 18.75 | 131.5 |
| 20.2 | 132 |
| 21.5 | 132.5 |
| 22.85 | 133. |
| 24. | 132.5 |
| 25. | 132.5 |

INSTRUMENTS

MAGNETO TACHOMETER #38

WESTON MILLI VOLTMETER {0-20, 0-200

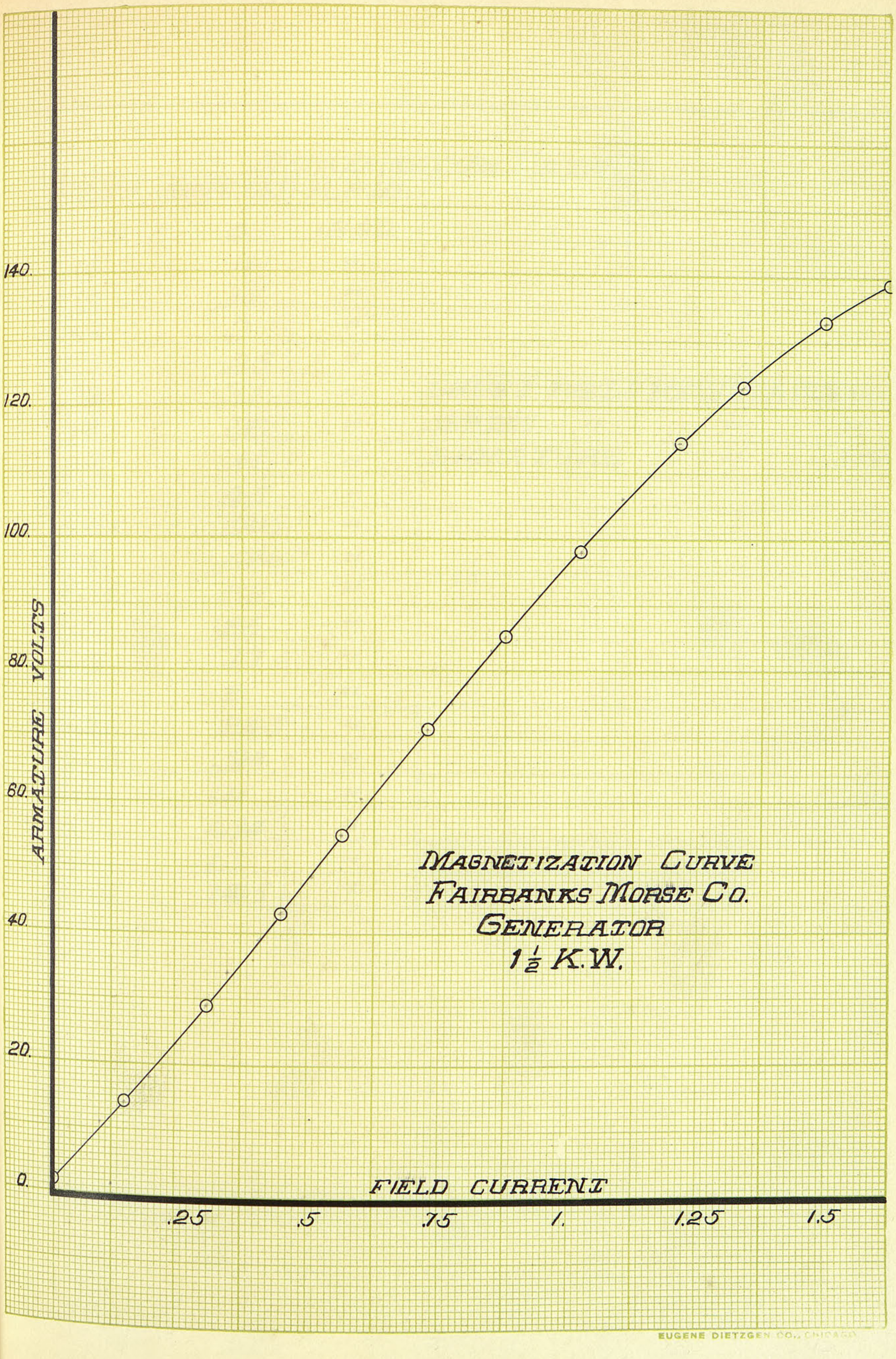
WESTON D.C. VOLTMETER [0-150]

WESTON D.C. AMMETER [0-15.]

On the other hand, cost of material and the desire for light compact machines, makes it necessary to use as great flux density as is consistent with good regulation.

Machines, therefore, except in special cases should be worked at a point just below the knee of the curve.

The curve is useful in determining the regulation and may show any faults in design, construction, or material. As the curve from this test is of the usual shape for machines of this size, the machine will give good voltage regulation and will not have excessive iron losses.


MAGNETIZATION CURVE
FAIRBANKS MORSE CO.
GENERATOR
1½ K.W.
ARMATURE VOLTS
FIELD CURRENT
0.
20.
40.
60.
80.
100.
120.
140.
.25
.5
.75
1.
1.25
1.5
EUGENE DIETZGEN CO., CHICAGO

## MAGNETIZATION DATA

| VOLTS | AMPERES | R.P.M. | |
|---|---|---|---|
| 1.5 | .0 | 1850 | |
| 11. | .11 | " | |
| 14. | .15 | " | |
| 18. | .2 | " | |
| 23. | .25 | " | |
| 29. | .31 | " | SHUNT FIELD RESISTANCE 69. OHM. |
| 34. | .36 | " | SERIES " " .11 " |
| 39. | .41 | " | ARMATURE " .519 " |
| 43. | .45 | " | |
| 48.5 | .505 | " | |
| 55. | .566 | " | |
| 60.5 | .62 | " | |
| 64. | .65 | " | |
| 75. | .77 | " | |
| 78. | .8 | " | |
| 83. | .845 | " | |
| 91.5 | .94 | " | |
| 108. | 1.11 | " | |
| 123. | 1.34 | " | |
| 133. | 1.5 | " | |
| 143.5 | 1.65 | " | |

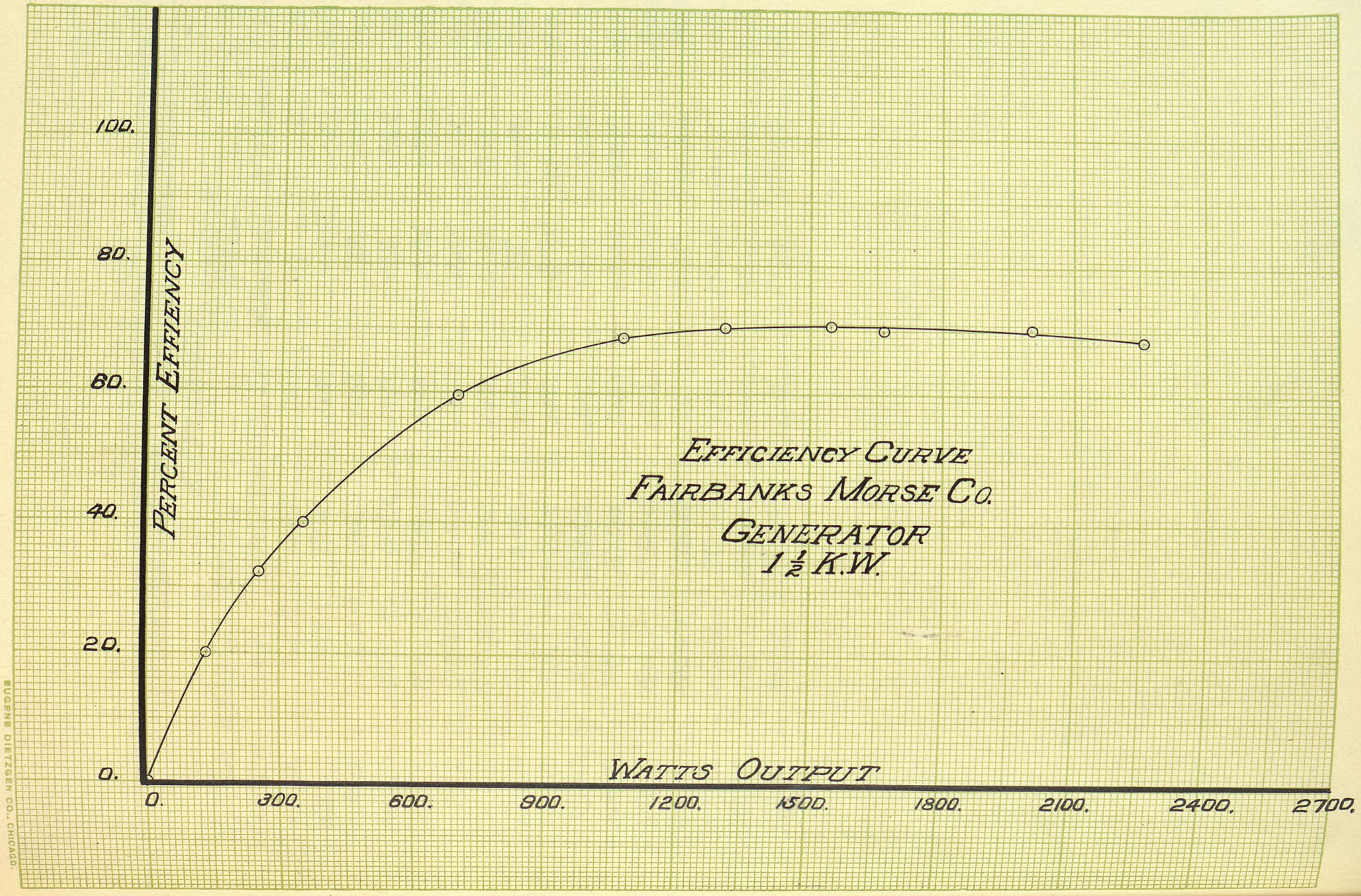
## Efficiency.

In determining the efficiency of the dynamo, the calibrated motor method was used. By means of a prony brake the motor was calibrated at the speed required. A curve is plotted with motor efficiency as ordinates and motor input as abscissas.

The motor is then belted to the dynamo and the dynamo connected to a bank of lamps for load. Instruments are placed so as to measure the motor power input and the generator power output.

Reference to the calibration curve of the motor makes it possible to determine the generator input. The commercial efficiency of a generator is equal to the power output divided by the power input. The curve is plotted with percent efficiency as ordinates and generator output as abscissas.

The curve shows a maximum efficiency at full load of 71%, at one fourth load the efficiency is 40%, at one half load it is 62%, and at three fourths load it is 69%. Above full load the efficiency is less than at full load, being 69% for 50% overload.



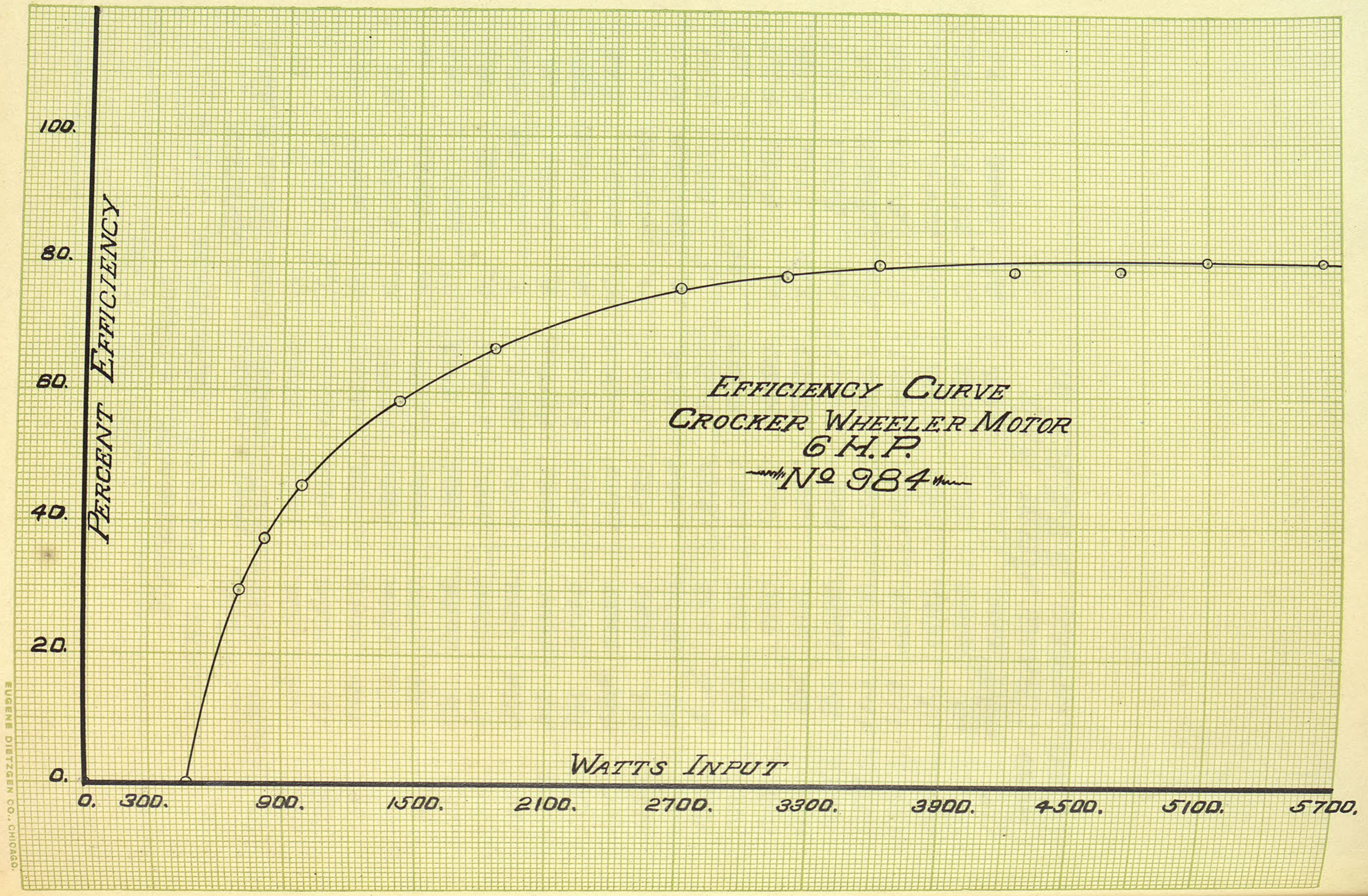
EFFICIENCY CURVE
FAIRBANKS MORSE CO.
GENERATOR
1½ K.W.
PERCENT EFFIENCY
WATTS OUTPUT
100.
80.
60.
40.
20.
0.
0.
300.
600.
900.
1200.
1500.
1800.
2100.
2400.
2700.
EUGENE DIETZGEN CO., CHICAGO.

# March 23 '06.

## Fairbanks Morse 1½ K.W. Generator

### Efficiency

| Motor Input Watts | Motor Input Eff. | Generator Input Watts | Generator Output Volts | Generator Output Ampere | Generator Output Watts | Generator Output Eff. |
|---|---|---|---|---|---|---|
| 1210. | 53% | 642. | 110. | 0. | 0. | 0. % |
| 1255. | 54.5 " | 684. | 110. | 1.25 | 137.5 | 20. " |
| 1366. | 57.5 " | 785. | 110. | 2.3 | 253. | 32.2 " |
| 1477. | 60. " | 887. | 110. | 3.2 | 352. | 39.7 " |
| 1667. | 64. " | 1865. | 110. | 4.25 | 467.5 | 44. " |
| 1747. | 65.5 " | 1145. | 110. | 5.25 | 577. | 51.2 " |
| 1879. | 67.5 " | 1268. | 110. | 6.35 | 698. | 59.5 " |
| 2059. | 70. " | 1440. | 110. | 7.6 | 836. | 66.2 " |
| 2365. | 73. " | 1725. | 110. | 9.75 | 1073. | 68.5 " |
| 3040 | 77.5 " | 2355. | 110. | 14.1 | 1550. | 70.8 " |
| 3205 | 78. " | 2500. | 110. | 15.15 | 1665. | 69.7 " |
| 3685. | 80. " | 2940. | 110. | 18.25 | 2008. | 68.2 " |
| 3665. | 80. " | 2930. | 110. | 18.2 | 2000. | 70.4 " |
| 3775 | 80.5 " | 3014. | 110. | 19.25 | 2120. | 68.6 " |
| 3895 | 80.5 " | 3135. | 110. | 19.5 | 2146. | 68.7 " |
| 4080 | 80.7 | 3290. | 110. | 20.5 | 2280. | 68.7 " |


EFFICIENCY CURVE
CROCKER WHEELER MOTOR
6 H.P.
No 984
PERCENT EFFICIENCY
100.
80.
60.
40.
20.
0.
WATTS INPUT
0.
300.
900.
1500.
2100.
2700.
3300.
3900.
4500.
5100.
5700.
EUGENE DIETZGEN CO., CHICAGO.

## April 1. '06.

### Efficiency Curve

### Crocker Wheeler Machine # 984.

| Input | | | | | Output | | |
|---|---|---|---|---|---|---|---|
| Volts | Load Amperes | Arm. Watts | Field Watts | Total Watts | Lbs. | Watts | Eff. |
| 105. | 3.2 | 336. | 136.5 | 472.5 | 0. | 0. | 0. |
| 109. | 10. | 1090. | 136.5 | 1226.5 | 1.5 | 623.5 | 50.8 |
| 109. | 11.8 | 1287. | 136.5 | 1423.5 | 2. | 830.8 | 58.3 |
| 111. | 15.5 | 1722. | 136.5 | 1858.5 | 3. | 1246. | 67. |
| 100. | 19.3 | 2130. | 136.5 | 2266.5 | 4. | 1661.6 | 73.4 |
| 111.5 | 23. | 2568 | 136.5 | 2704.5 | 5. | 2077. | 76.6 |
| 113. | 27. | 3050 | 136.5 | 3186.5 | 6. | 2492. | 78.3 |
| 114 | 30.4 | 3468. | 136.5 | 3604.5 | 7. | 2907.6 | 80.8 |
| 116.5 | 35. | 4080 | 136.5 | 4216.5 | 8. | 3323. | 79. |
| 117. | 39. | 4565 | 136.5 | 4701.5 | 9. | 3738.8 | 79.5 |
| 117. | 42.4 | 4960 | 136.5 | 5096.5 | 10. | 4154. | 81.6 |
| 114. | 47. | 5360 | 136.5 | 5496.5 | 11. | 4568.4 | 83.3 |
| 114. | 48 | 5475 | 136.5 | 5611.5 | 11. | 4568.4 | 81.4 |
| 106. | 5.5 | 583 | 129.7 | 712.7 | .5 | 207.7 | 29.1 |
| 107.5 | 6.5 | 700 | 129.7 | 829.7 | .75 | 311.5 | 37.5 |
| 107. | 7.3 | 780 | 129.7 | 909.7 | 1. | 415.5 | 45.7 |
| 108. | 8.5 | 918. | 129.7 | 1047.7 | 1.25 | 519.2 | 49.6 |
| 108.5 | 9.3 | 1008. | 129.7 | 1137.7 | 1.5 | 623.3 | 54.7 |
| 108.5 | 11.3 | 1226. | 129.7 | 1355.7 | 2. | 830.8 | 61.5 |
| 108. | 11.4 | 1232. | 129.7 | 1361.7 | 2. | 830.8 | 60.5 |
| 109. | 15. | 1635. | 133.5 | 1768. | 3. | 1246. | 70.2 |
| 111. | 23. | 2553. | 133.5 | 2689. | 5. | 2077. | 77.2 |
| 114 | 38.5 | 4380. | 133.5 | 4516. | 9.5 | 3946. | 87.5 |

Prony Brake Arm 3 Ft.

Motor Speed 975 R.P.M.

## Temperature Rise.

Temperatures of the different parts of the generator were taken at the end of a ten hour run at full load and were found to come well within the allowable limit. The temperatures at the end of a ten hour run were:

| | |
|---|---|
| Armature | 46°C |
| Commutator | 50°C |
| Field Winding | 44°C |
| Bearings | 47.5°C |
| Yoke | 38°C |
| Room | 30°C |

The engine is a vertical two horse-power, four cycle throttle governing engine. The cylinder is placed above an air tight chamber in the base. This chamber has a quantity of oil in the bottom so that as the crank rotates, it dips in this oil throwing it against the sides of the chamber. Grooves cut in the frame lead the oil to the main bearings and the gear shaft. In this way the main bearings, crank and the gear shaft are oiled automatically so that the only part requiring separate oiling is the cylinder. An oil cup placed on the side of the cylinder oils this, and all surplus oil supplied to the cylinder falls to the reservoir below.

The inlet or mixing valve is an ordinary check valve, automatic in its action. The exhaust valve is constructed the same as the mixing valve and is operated by means of a cam and lever on the gear shaft.

The sparker is of the make and break type, and operates from the gear shaft thus making and breaking the circuit every other revolution. The time of ignition can be adjusted by a screw and when properly adjusted the screw may be secured by a lock nut. A set of six Gladstone cells with a spark coil furnish the necessary current.

A centrifugal governor on the gear shaft operates the valve supplying air to the mixing chamber. An increase of speed causes the governor to partly close the valve reducing the air supplied, thus increasing the richness of the mixture. The increased richness of the mixture decreases the power of the explosion, thus reducing the speed. Where very constant speed is required this type of governor has an advantage over the hit or miss governor, for if an explosion were missed the speed would drop below normal and would rise above normal again before the governor would open the sparker circuit.

The gasoline tank is placed below the level of the engine and a pump operated from the gear shaft keeps a supply of oil in the reservoir on the side of the cylinder. A stop cock in the supply pipe limits the amount of oil pumped.

A pipe leading from the bottom of the reservoir to the oil tank carries the surplus oil back to the tank. This pipe extends upward inside the reservoir and holds the oil at the proper level.

The throttle valve regulates the amount of gasoline supplied to the engine and should be set so as to give maximum speed when the engine is working.

The speed of the engine may be changed by changing the tension of the springs on the governor or by changing the length of the rod extending from the governor to the air valve. For a large change of speed the length of the rod must be changed but for smaller changes the spring tension will be sufficient. The speed of the engine cannot be changed to any extent while the engine is running.

A water tank connected to the water jacket of the cylinder keeps the temperature within working limits.

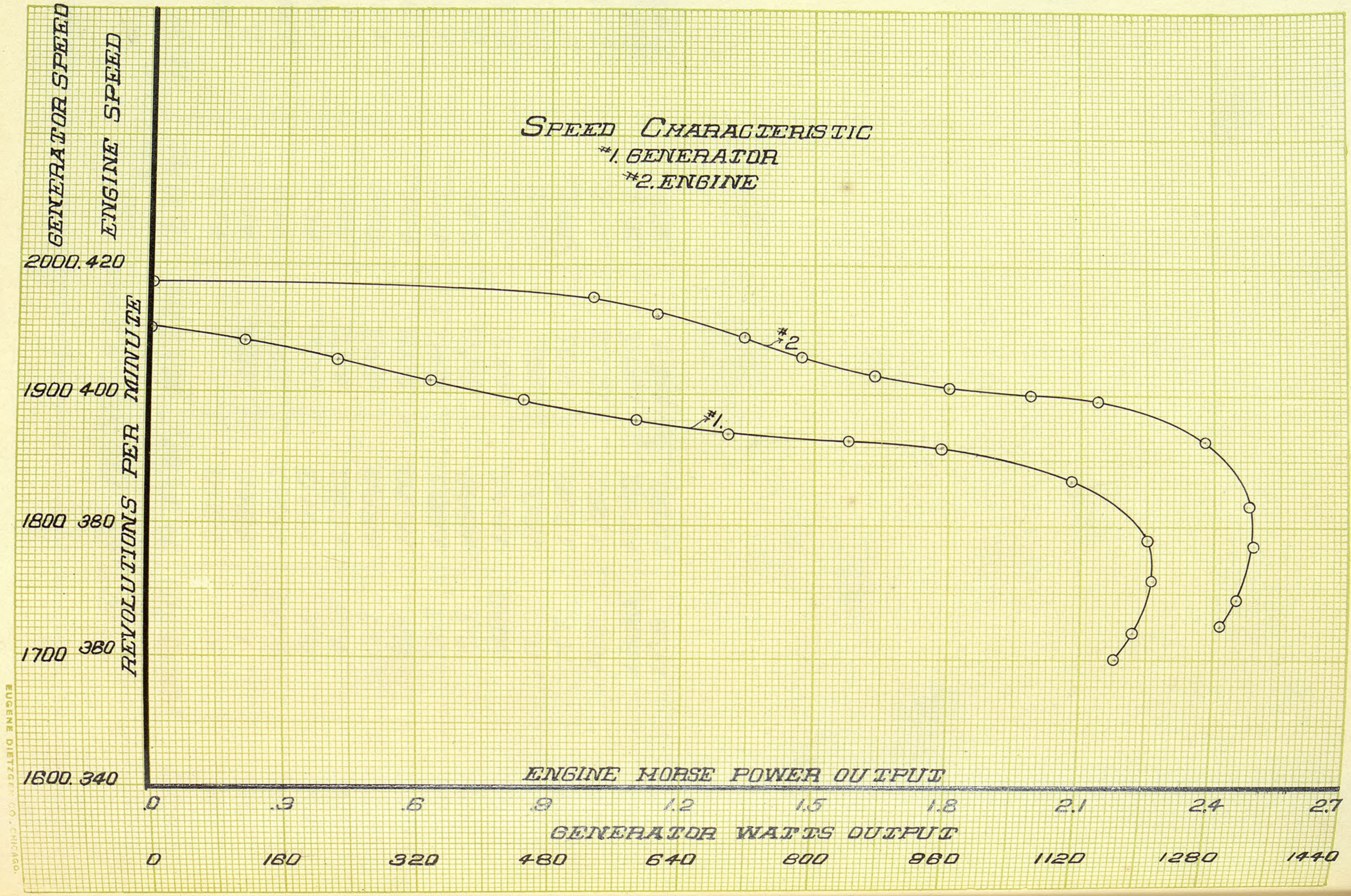
To start the engine disconnect oil pump from the gear shaft, pump until the reservoir is filled with oil, close battery switch, open throttle valve to (1), by means of starter crank, turn engine rapidly until the first explosion takes place, close throttle valve to the position in which it gives best results, and apply load.

To stop the engine close the throttle valve and open battery switch. A very few turns of the crank were sufficient to start the engine, three revolutions being sufficient in some cases. If the oil reservoir is full and the first revolution comes on the compression stroke, three quick turns will start the engine.

The engine has fly wheels twenty eight inches in diameter and the generator pulley is six inches in diameter. The governor on the engine was adjusted so as to give the engine a speed of 400 R.P.M. at full load. When the engine runs at 400 R.P.M. the generator runs at rated speed (1850 R.P.M.).

The speed at no load was 420 R.P.M. and gradually decreased as the load increased. After full load is reached the speed drops off rapidly as shown by the speed curve and continues to drop even with a decrease in load.

The curve is plotted with R.P.M. as ordinates and load as abscissas. Maximum load (2.3 HP) was obtained at a speed of 378 R.P.M.



SPEED CHARACTERISTIC
#1. GENERATOR
#2. ENGINE
GENERATOR SPEED
ENGINE SPEED
REVOLUTIONS PER MINUTE
2000. 420
1900 400
1800 380
1700 360
1600. 340
#1.
#2
ENGINE HORSE POWER OUTPUT
.0
.3
.6
.9
1.2
1.5
1.8
2.1
2.4
2.7
GENERATOR WATTS OUTPUT
0
160
320
480
640
800
960
1120
1280
1440
EUGENE DIETZGEN CO. CHICAGO.

# SPEED REGULATION

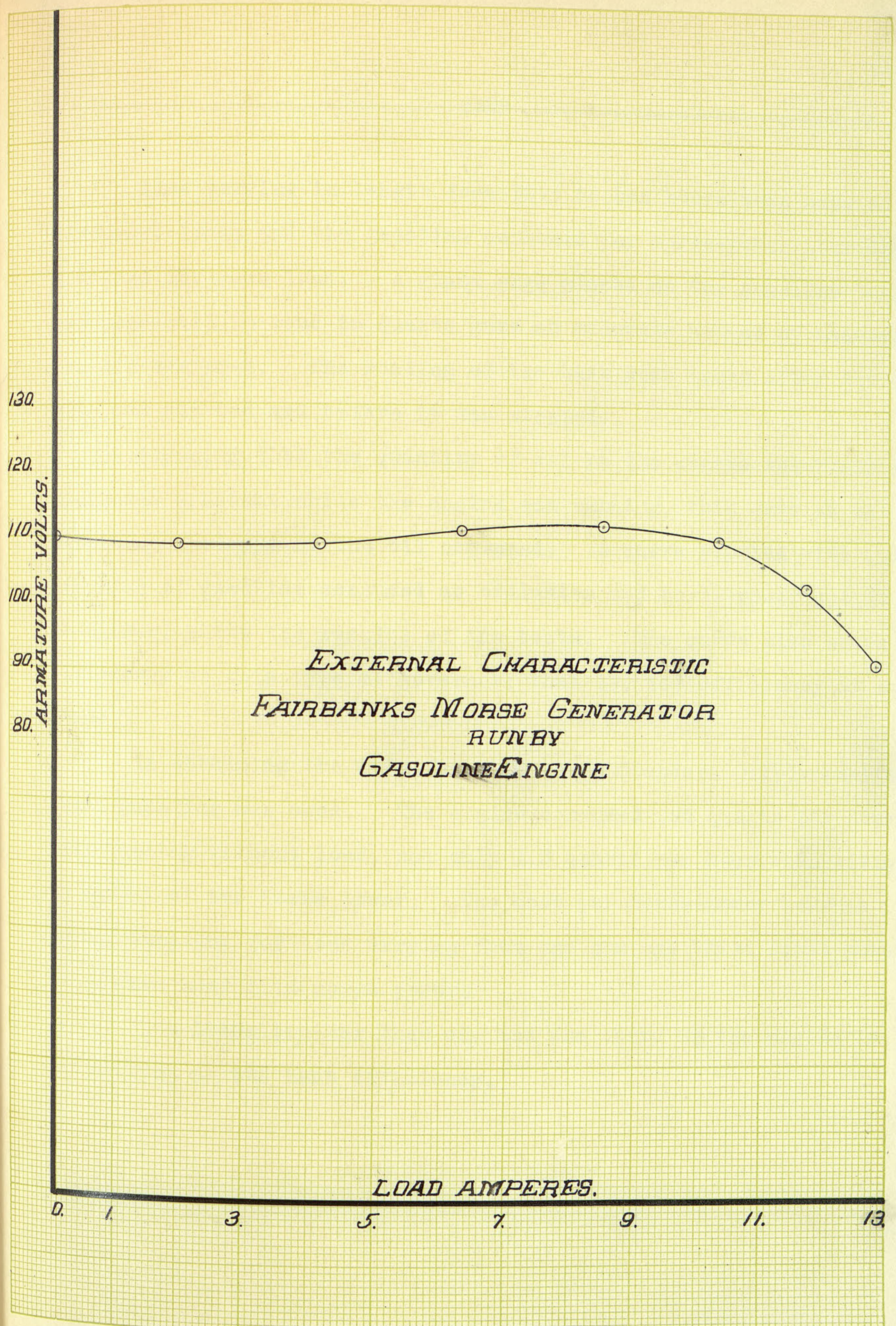
| GENERATOR | | | | ENGINE | |
|---|---|---|---|---|---|
| VOLTS | AMPERS | R.P.M. | WATTS | R.P.M. | H.P. |
| 110. | 0. | 1950. | 0. | 417. | .86 |
| 109. | 1. | 1940. | 109. | 415. | 1. |
| 109. | 2.05 | 1925. | 223. | 412. | 1.16 |
| 109. | 3.1 | 1910. | 338. | 409. | 1.34 |
| 109. | 4.15 | 1895. | 452. | 406. | 147 |
| 110. | 5.3 | 1880. | 583. | 403. | 164 |
| 110. | 6.3 | 1870. | 699. | 401. | 1.8 |
| 112. | 7.5 | 1865. | 840. | 400. | 1.99 |
| 112. | 8.5 | 1860. | 952. | 399. | 2.14 |
| 110. | 9.99 | 1835. | 1133. | 393. | 2.38 |
| 106. | 11. | 1800. | 1166. | 385. | 2.42 |
| 103. | 11.7 | 1790. | 1205. | 383. | 2.48 |
| 99. | 12.2 | 1760. | 1210. | 377. | 2.49 |
| 96. | 12.35 | 1720. | 1185. | 369. | 2.45 |
| 91. | 12.8 | 1700. | 1164. | 365. | 2.42 |

The external characteristic curve of the generator, when run with the engine shows how well the over-compounding of the generator compensates for the drop in speed of the engine. The curve is plotted with volts as ordinates and amperes load as abscissas. Starting at 110 volts with no load the curve rises slowly to 112 volts at three fourths load, then falls to 111 volts at full load, and drops quite rapidly from this point as the load is increased. This shows a variation of fully two volts as the load varies from zero to full load without change of rheostat.

As another test of the speed regulation, snap switches were placed in the circuit so that any desired portion of the load could be thrown on or off. One fourth, one half, three fourths and full load were thrown on by closing the switch with no noticeable jar or fluctuation in voltage. The speed changed in a very few seconds on the curve corresponding to the load applied.

There was a variation of voltage with each explosion but it was so small that it was hard to detect by looking at the lamps. A Weston D.C. voltmeter shows a fluctuation of one volt with each explosion.

When running with constant load the generating unit would run for ten hours without a variation of over three volts from normal. This shows a regulation of less than three percent.



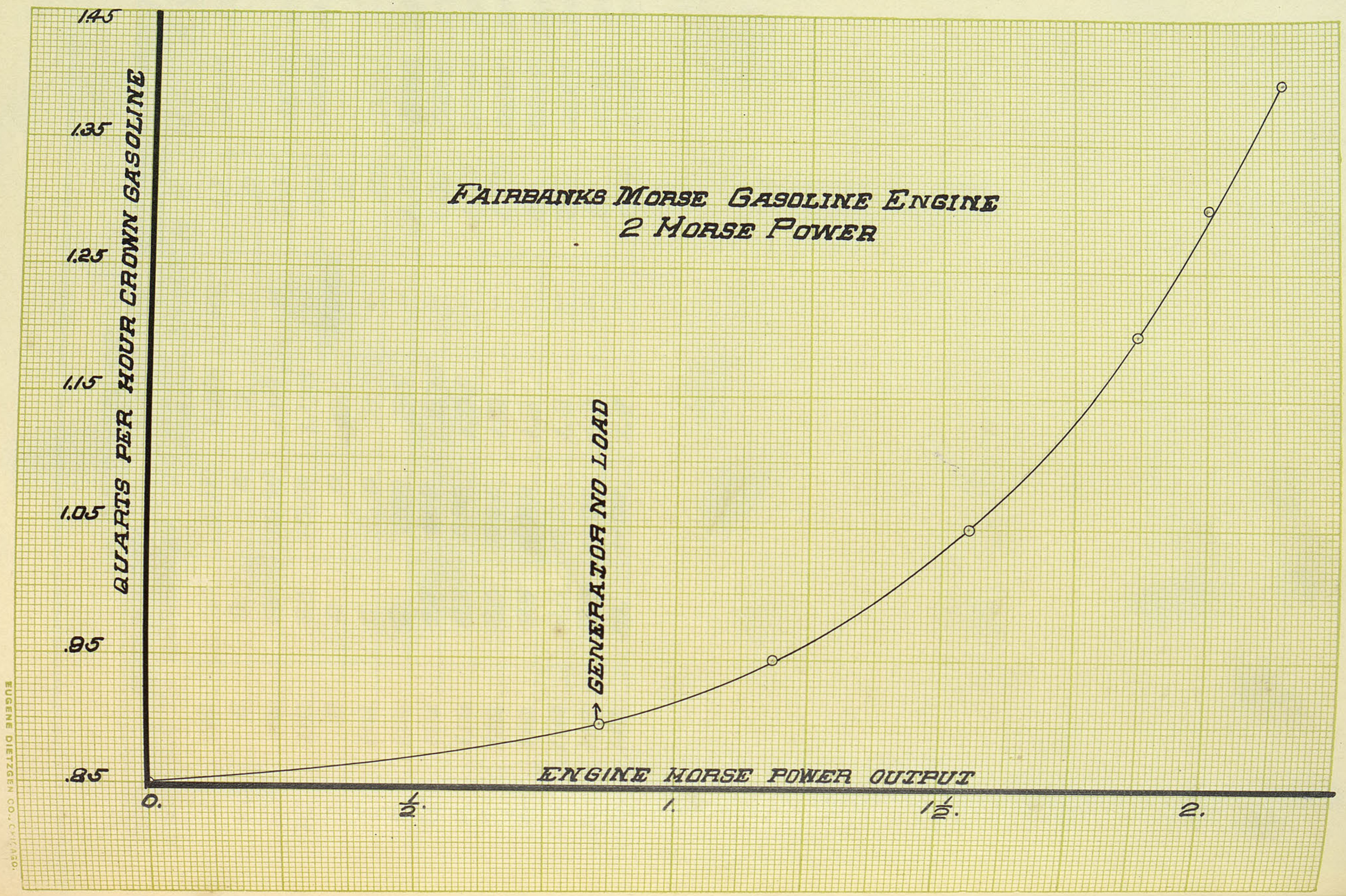
130.
120.
110.
100.
90.
80.
ARMATURE VOLTS.
EXTERNAL CHARACTERISTIC
FAIRBANKS MORSE GENERATOR
RUN BY
GASOLINE ENGINE
LOAD AMPERES.
0.
1.
3.
5.
7.
9.
11.
13.
EUGENE DIETZGEN CO., CHICAGO.

Runs varying in length from five to ten hours were made at different loads and the gasoline consumed per horse-power hour determined for each load. A glass gage placed on the gasoline tank and graduated to read in quarts gave an accurate method of measuring the oil consumed. The reading of the tank were taken after the engine was started and before it was stopped.

Assuming that the quantity of oil in the engine reservoir and pipes was constant while the engine was running, this gave an accurate measurement of the oil consumed. A curve plotted with quarts per hour of gasoline consumed as ordinates and horse-power output as abscissas, shows the results of the tests. The curve also shows the efficiency of this type of governor; that is, low efficiency at small loads.

In obtaining the data for this curve Standard Oil Company's Crown gasoline was used. The engine consumed .85 quarts per hour when running without load, and only 1.3 quarts per hour when giving an output of two horse power. The cost per horse-power hour is nearly constant for load varying from one and one third horse-power to maximum load 2.14 horse power.

With loads smaller than one and one third HP the engine is not working at its best efficiency.


FAIRBANKS MORSE GASOLINE ENGINE
2 HORSE POWER
QUARTS PER HOUR CROWN GASOLINE
1.45
1.35
1.25
1.15
1.05
.95
.85
GENERATOR NO LOAD
ENGINE HORSE POWER OUTPUT
0.
1/2.
1.
1 1/2.
2.
EUGENE DIETZGEN CO., CHICAGO.

# COST TEST

| RUN | GENERATOR | | | GASOLINE | | ENGINE OUTPUT | COST PER HOUR | |
|---|---|---|---|---|---|---|---|---|
| HOURS | VOLTS | AMPERE | WATTS | QUARTS PER HOUR | GRADE | H.P. | H.P. | K.W. |
| 3. | 110. | 5.5 | 550. | 1.166 | 87° | 1.4 | .0418 | .106 |
| .25 | 0. | 0 | 0. | .7 | " | .0 | -- | -- |
| 2.25 | 110. | 9.8 | 1056. | 1.111 | " | 2.05 | .0271 | .0528 |
| 10. | 110. | 9.5 | 1058. | 1.175 | " | 2.05 | .0288 | .0556 |
| 5. | 0. | 0 | 0. | .85 | CROWN | .0 | -- | -- |
| 5. | 110. | 0 | 0. | .9 | " | .86 | .0393 | -- |
| 5. | 110. | 2 | 220. | .95 | " | 1.18 | .0302 | .1635 |
| 8. | 110. | 4.2 | 462. | .875 | " | 1.33 | .0246 | .071 |
| 5. | 110. | 6.3 | 693. | 1.05 | " | 1.55 | .0254 | .0645 |
| 5. | 110. | 8.5 | 935. | 1.2 | " | 1.87 | .0241 | .0481 |
| 8. | 110. | 9.3 | 1023. | 1.3 | " | 2. | .0244 | .0477 |
| 10. | 110. | 9.3 | 1023. | 1.3 | " | 2. | .0244 | .0477 |
| 10. | 110. | 9.3 | 1023. | 1.3 | " | 2. | .0253 | .0495 |
| 5. | 110. | 10. | 1100. | 1.4 | " | 2.14 | .0248 | .0478 |

The generator efficiency rises rapidly with load and does not reach full efficiency until nearly full load is reached. Sixteen lamps taking 8.5 amperes is the smallest load at which the unit will work at its best efficiency. For smaller loads the cost per K.W. hour increases rapidly and above this point the cost is about constant. With a load of four lamps (16 c.p.) the cost per K.W. hour is $0.1635 or the cost of running four lamps for one hour would be $0.0356. With a load of 16 lamps the cost per K.W. hour is $.048 or the cost of running sixteen lamps for one hour is $0.045. This shows the advantage of working full load, an additional twelve lamps being run for one hour by increasing the cost $0.01 per hour. An increase in the output of 300% only increases the cost 30%.

When working at full load the cost per horse power hour output of the engine is $0.0244 and the cost per K.W. hour output of the generator is $0.0477 using Crown gasoline at 15 cents per gallon.

Several runs were made with 87° gasoline so that a comparison could be made of the two grades. Taking the cost of 87° gasoline at 20 cents per gallon and Crown gasoline at 15 cents per gallon, the Crown proved to be the cheaper for a given power output. For two runs of equal output one using 87° gasoline and the other Crown gasoline, the costs per horse-power hour were $0.0286 for 87° gasoline and $0.0244 for Crown gasoline.

The regulation when using 87° gasoline was better than when using Crown gasoline but not enough to warrant its use.

A test was also made on the engine when current for the sparker was taken from the generator. Two lamps in parallel were connected in series with the spark coil on the generator circuit and the terminals connected through a double pole double throw switch to the spark plug.

The other terminals of the switch were connected to the battery. Throwing the switch to the side connected to the battery the engine could be brought up to speed and the generator to voltage then throwing the switch to the opposite position, the sparker operated on the generator circuit. Placing the sparker on the generator circuit did not affect the voltage regulation. Using this method of sparking would prolong the life of the batteries as they would only be used a few minutes on starting, and the amount of energy taken from the generator was very small.

The water in the cooling tank reached a temperature of about 85°C after a few hours run and remained at that temperature during the remainder of the run. During a ten hour run at full load the amount of water evaporated was about twelve gallons.

The lubricating oil should be supplied to the cylinder faster than needed at the cylinder so that the surplus will keep the oil in the base of the engine at a constant level.

Very little care is required in the operation. After the engine is started and the voltage adjusted no further care is required other than supplying oil and water.

For gaskets on the cylinder asbestos one sixteenth of an inch thick gave the best results. Paper or rubber gaskets would stand but a few hours.

As a whole the tests were very satisfactory. The voltage regulation was good, the amount of care required was very small and no bearings showed any tendency to heat. The efficiency and cost test were all that could be expected from so small a unit, $0.048 per K.W. hour being a low cost for electrical power.