GENERAL ELECTRIC REVIEW

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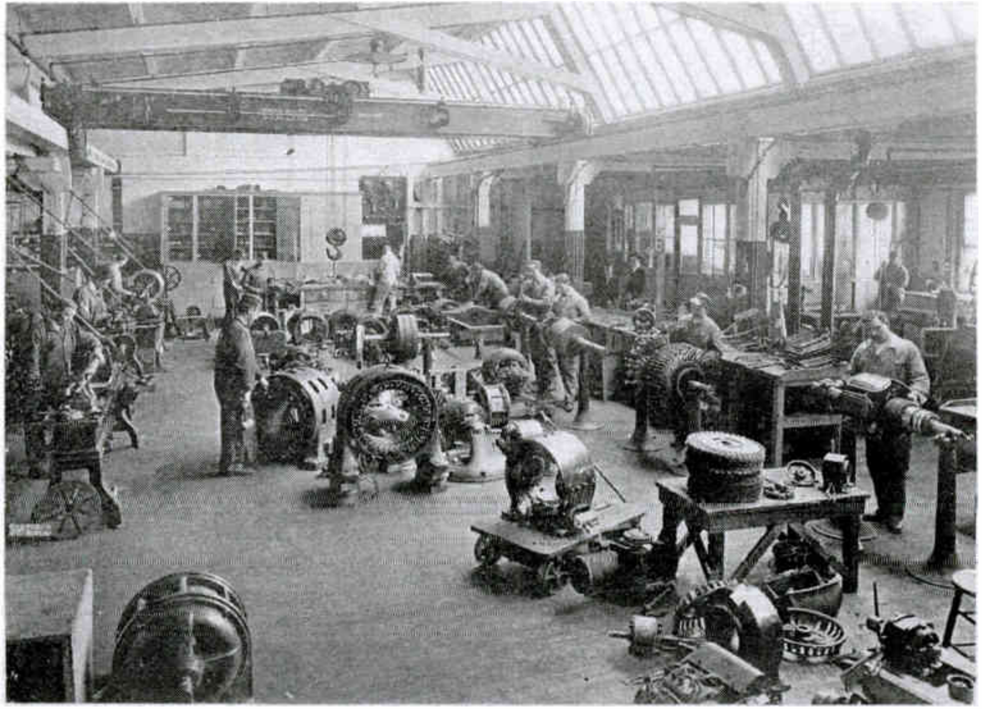

Armature Winding; General Motor and Armature Repairs. Repair Shop of the General Electric Company, Chicago

(See Page 297)

GENERAL ELECTRIC
REVIEW

COMETS

The origin, behavior and composition of comets have long been matters of speculation amongst astronomers. Owing partly to the somewhat rare appearance of large comets and to the fact that refined spectroscopic methods have only been available recently, little is at present actually known about their composition or the causes underlying the formation of the tail, which is so marked a phenomenon attending many comets. Prof. Thomson's article in this issue of the Review, which deals with the forces causing comets' tails and the possible source from which sufficient material is derived for their maintenance, is extremely opportune just now, since, historically speaking, the most noted comet has been visible for the last two months.

A great part of the article is very suggestive, especially that relating to the genesis of the new tail which occurs as the comet nears the sun, when it is subjected to maximum radiation. As the author points out, the matter composing the tail must be extremely attenuated and the mass of the nucleus very small. In no case has any perturbation of a planet been observed due to proximity of a comet, although the orbits of comets have been considerably altered by planets; hence only a higher limit can be set for the total mass, which is but a minute fraction of the earth's—certainly less than one-hundredth-thousandth part.

Astronomers divide comets into two groups: the parabolic and periodic. The former revolve in practically parabolic orbits; that is to say, their orbits are either very elongated ellipses, with periods measured in hundreds of years, or are slightly hyperbolic. These comet pass out into space far beyond the orbit of the furthest planet and acquire at perihelion, when their distance from the sun is minimum, a velocity which is practically that which would be acquired by a body falling from rest at infinity to a point at perihelion distance from the sun. It is interesting to note that this velocity is the same as that which the comet would acquire by falling from its position at perihelion to the sun's center under the uniform gravitational acceleration of the sun at the perihelion position. This velocity is the greater the nearer the comet passes to the sun's surface, its limiting value being approximately 380 miles per second. A few comets have been observed for which this velocity has been nearly attained, notably the great comets of 1843 and 1882. The former comet at perihelion passed within 100,000 miles of the sun's surface, traversing the inner part of the corona. So fast did it travel that 180 degrees of its orbit were completed in less than two and a quarter hours, the maximum velocity being slightly over 360 miles per second.

The great comet of 1882 passed nearly as close to the sun and its brilliance was sufficient for it to be visible for three consecutive days, its passage up to the sun's disc being clearly observed at Cape Town. The brightness then appeared equal to that of the sun itself, but on crossing the sun's limb the comet vanished; on emergence a few minutes later, it was again clearly seen and could be followed telescopically until 480,000,000 miles away. The paths and velocities of these comets were not affected by their close proximity to the sun at perihelion, proving that the matter contained in the sun's corona is extremely attenuated; no resistance to motion was perceptible.

Periodic comets, of which Halley's is an example, have paths of which the major axes are comparable to planetary distances. Jupiter, the largest planet in our system, has a family of his own, whose paths extend close to his orbit. Halley's comet, known to history from Chinese annals as early as 12 B.C., is a Neptune comet, its aphelion distance being slightly greater than Neptune's distance from the sun. In consequence of this fact, the comet's orbit has been somewhat disturbed when Neptune chanced to be at the right point of his path during the comet's aphelion; but since the plane of the comet makes an angle of about 18 deg. with the plane of the ecliptic, and the major axis a slightly less angle, Neptune can never have been sufficiently close to have attracted the comet strongly. So far observed, Halley's is the only periodic comet moving in a retrograde direction around the sun, all the others travelling in the same sense as the planets.

The perihelion distance of this comet is about 60,000,000 miles, and the aphelion distance about 3,000,000,000 miles, so that its path is highly elongated and gives a very different orbit from the relatively circular orbits of the planets. At aphelion it has a velocity of less than one mile per second, whereas the perihelion velocity is about 30 miles per second, these two velocities being inversely proportional to the comet's distance from the sun at these points.

Prof. Thomson's suggestion as to the possibility of a comet picking up material as it traverses its long journey through space removes a difficulty as to the source from which a comet draws the supplies necessary for tail formation. Many of the materials composing a comet's nucleus are still unknown, but a few have been recognized by spectroscopic analysis; *viz.*, carbon in the form of hydrocarbons, cyanogen, carbonic oxide, iron, sodium, and possibly hydrogen. Bright bands have also been observed in the spectrum of the nucleus, of unknown origin.

The light from comets' tails is probably electrical in origin and is closely analogous to the light obtained from a vacuum tube; it is not due to temperature radiation. At perihelion, a comet may absorb electrical radiations of high frequency from the sun, radiating them at lower frequency; that is to say, the light from the tail may be due to phosphorescence.

The repulsion of the particles forming the tail when passing around the sun is probably due to electrical forces, although reflected sunlight may be in part the cause. As, however, the matter forming the tail is bombarded by electrified particles from the sun, electrostatic repulsion between it and the electrified surface of the sun is very likely the reason for the motion of the tail. However this may be, the cause is still unsettled and much more observation and experiment is required before a true theory is discovered.

Comets' tails are usually curved and as many as three distinct tails emanate from some comets, those most strongly curved being formed of the heaviest material. Observation proves that the repulsive force, whatever its cause, overcomes the gravitational and, acting on the surface of the tail particles, is relatively the more important the lighter these particles are, since any gravitational action of the sun is exactly proportional to the mass of each particle and independent of its surface area.

W. E. Miller

STARTING RESISTANCE FOR SERIES MOTORS

The article by Mr. E. R. Carichoff and Prof. Harold Pender on the determination of resistance steps for the acceleration of series motors, which appears on another page of this issue, forms an interesting and entirely new solution of a problem of much importance. In general, the steps in the starting rheostat of series motors are few in number, and it is essential that their value be accurately determined, as otherwise wide variations in starting current must result and a gradual and even acceleration will be impossible. While the lack of smooth acceleration is undesirable in nearly all classes of electric drive, it is particularly so where the motors are used for traction purposes. Here the sudden and uneven acceleration of the car is, as we all know, exceedingly annoying.

While a number of attempts have been made to deduce a rigid mathematical solution of the problem of determining starting resistances, the subject is somewhat complex and the present article is the first accurate mathematical solution that we remember to have seen. Generally speaking, in designing rheostats for new types of machines, the values for the resistance steps have been arrived at by trial—by comparison with other cases that have been found sufficiently accurate with other motors. Graphical methods may be employed for the purpose, but these also involve trial and error. The present accurate analytical method should therefore prove of much value.

NOTES ON THE MAGNITUDE OF THE LOSSES INCIDENTAL TO THE TRANSFORMATION OF THE ENERGY IN COAL INTO ELECTRICAL ENERGY*

PART I

By Dr. Ernst J. Berg

The specific case of a 1000 kw. steam turbine station has been chosen to illustrate the heat balance in the conversion into electrical energy of the energy in coal.

It will be assumed that the combined efficiency of the turbine and generator is 65 per cent. and that the turbine is supplied with steam at 200 lbs. absolute pressure and 150° F. superheat; and, further, that the condenser pressure is 0.75 lb. absolute, or that corresponding to a 28.4 in. vacuum with a barometer pressure of 30 in.

The available energy in foot-pounds in each pound of superheated steam, when expanded adiabatically from a given pressure and superheat to the pressure of the vacuum, is the difference between the total heat input and that which is left as liquid heat and latent heat in the mixture at the lower pressure.

Thus

$$E = 778\,[H_1 + C_p t_1 - (q_2 + x_2 r_2)] \qquad (1)$$

where H_1 = total heat of sat. steam at initial press p_1

C_p = spec. heat of superheated steam

t_1 = superheat in ° F. at pressure p_1

q_2 = heat of liquid at lower pressure p_2

x_2 = quality of the steam at the pressure p_2

r_2 = latent heat at the pressure p_2

The steam tables enable us to insert all values in the above equation except the value of x_2. This quantity is known from the fact that the entropy is constant before and after the expansion; that is, the mathematical expression entropy, which is the ratio of the heat received to the absolute temperature of reception, is constant. The entropy of superheated steam $= C_p \log_e \frac{T_1 - t_1}{T_1} + \frac{r_1}{T_1} + \phi_1$. (2)

The entropy of moist steam $= \frac{x_2 r_2}{T_2} + \phi_2$; (3)

thus $x_2 = \frac{T_2}{r_2}\left(C_p \log_e \frac{T_1 + t_1}{T_1} + \frac{r_1}{T_1} + \phi_1 - \phi_2\right)$ (4)

In the particular instance referred to above we have—

p_1 = 200 lbs. abs.

p_2 = 0.75 lbs. abs.

H_1 = 1193.3 (from steam tables)

C_p assumed to be = 0.5

T_2 = 92.1° F. = 552.1° abs.

T_1 = 381.6° F. = 841.6° abs.

t_1 = 150° F. Superheat at p_1

r_1 = 843.4 latent heat at p_1

r_2 = 1049.8 latent heat at p_2

ϕ_1 = 0.5429 entropy of the liquid

ϕ_2 = 0.1152 entropy of the liquid

$$\text{Thus } x_2 = \frac{552.1}{1049.8}\left[0.5\left(2.3 \log_{10} \frac{841.6+150}{841}\right) + \frac{843.4}{841.6} + 0.5429 - 0.1152\right] = 0.8 \qquad (5)$$

Substituting this value in the energy equation above we get—

$$E = 778\left[\left(1198 + (0.5 \times 150)\right) - \left(60.2 + (0.8 \times 1049.8)\right)\right] = 290{,}000 \text{ ft. lbs.} \qquad (6)$$

Since 1 kw. hr. is equivalent to $\left(\frac{1000}{746} \times 33{,}000 \times 60\right) = 2{,}654{,}000$ ft. lbs., the amount of steam consumed per kilowatt hour under these conditions will be—

$\frac{2{,}654{,}000}{290{,}000} = 9.15$ lb., which is the theoretical water rate; but since the efficiency of the turbine is only 65 per cent., the real water rate will be—

$$\frac{9.15}{0.65} = 14.1 \text{ lb. per kw. hr.} \qquad (8)$$

Therefore the total flow for 1000 kw. hr. is 14,100 lbs. per hour. The total heat in each pound of superheated steam, assuming $C_p = 0.5$, is $1198.3 + .5 \times 150 = 1273.3$ B.t.u. (9) Thus the total heat of 14,100 lbs. is $14{,}100 \times 1{,}273.3 = 17{,}960{,}000$ B.t.u. (Since one kw. hr. corresponds to 3,410 B.t.u., the energy converted to electricity.) Therefore the energy not converted is 14,550,000, or 81 per cent. (10)

Some of these losses are caused by the generator windage, copper and iron losses,

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* The first of a series of three papers read before employees of the Commonwealth Edison Company. The second and third papers will be published later.

THEORETICAL WATER RATE

for Various Values of Pressure, Vacuum and Superheat

SUPERHEAT		200°	150°	100	50°	0°
Lbs. Abs Pres	In. Vac.	Theoretical W.R.				
215	29	8.45	8.7	8.95	7.2	9.45
215	28	9.	9.25	9.5	9.75	10.
215	27	9.5	9.75	10.05	10.3	10.55
215	26	9.9	10.2	10.50	10.8	11.11
215	20	11.65	12.07	12.50	12 87	13.25
215	10	13.65	14.15	14.65	15.13	15.65
215	0	15 25	15.8	16.4	16.9	17.4
215	2 lb. bk. pres.	15.65	16.07	17.1	17.6	18.2
200	29	8.55	8 8	9 05	9.32	9.6
200	28	9.1	9.4	9.7	9 95	10.2
200	27	9.6	9.9	10.2	10.45	10.75
200	26	10.	10.32	10 65	10.97	11.3
200	20	11 75	12.4	12 8	13.2	13.6
200	10	14	14.5	15.05	15.57	16.
200	0	15.6	16.2	16.9	17.4	17.9
200	2 lb. bk. pres.	16.3	16.9	17 5	18.	18.7
175	29	8.75	9.02	9.3	9.55	9.8
175	28	9.35	9.62	9.9	10.18	10.45
175	27	9.85	10 15	10.45	10.75	11.05
175	26	10.3	10.65	11.	11.3	11.6
175	20	12 4	12 82	13 25	13.65	14.05
175	10	14 65	15.77	15.70	16.25	16.8
175	0	16 4	17 35	18.3	18.6	18.9
175	2 lb. bk. pres.	17.1	17 73	18 4	19.1	12.8
165	29	8.85	9.12	9.4	9.63	9.80
165	28	9 45	9 72	10.	10.3	10.6
165	27	10.	10.32	10.65	11.	11.3
165	26	10.5	10 85	11.2	11.55	11.9
165	20	12 6	13 05	13.5	13.9	14.3
165	10	14 9	15.05	16.1	16.57	17.05
165	0	16 85	17.52	18.2	18.75	19.3
165	2 lb. bk. pres.	17 6	17.3	19.	. . . .	20.3
140	29	9 12	9.37	9.65	9.9	10.2
140	28	9 75	10 05	10.35	10.65	10.95
140	27	10.3	10 62	10.95	11.28	11.62
140	26	10 85	11 20	11.55	11.95	12.3
140	20	13 1	13.6	14.1	14.6	15.1
140	10	15 8	16 4	17.	17.6	18.2
140	0	17.9	18.6	19.3	20.	20.65
140	2 lb. bk. pres.	18 6	18.95	20 3	21.	21.8
125	29	9.35	. . . .	9.88		10.4
125	28	10.03		10.6	. .	11.2
125	27	10 70		11.3	11.6	11.9
125	26	11 23		11.9		12.55
125	20	13.65		14.6		15.50
125	10	16 50		17.7		18.98
125	0	18 90		20.4		21.80
125	2 lb. bk. pres.	19 85		21.6		23.1
100	29	9.77		10.25		10.89
100	28	10 50		11.16		11.72
100	27	11.2		11.9		12.50
100	26	11 83		12.65		13.23
100	20	14 70		15.80		16.65
100	10	18		19.45		20.7
100	0	20 9		22.28		24.25
100	2 lb. bk. pres.	22.15		24.25		25.82
Atmos. (14.7 lbs.)	29	15 4		16.65		17.7
Atmos. (14.7 lbs.)	28	17.65		19.1		20.4
Atmos. (14.7 lbs.)	27	20.		21.8	. .	23.3
Atmos. (14.7 lbs.)	26	22 40		24.5		25.4
10 in. Vac. (10 lbs.)	29	17.25		18.8		20.2
	28	20.20		22.1		24.2
	27	23.50		25 8		28.6
	26	26.95		30.	. .	33.

and some by the bearings. These losses, which have nothing directly to do with the steam, amount to about 6 per cent. of the electrical output, or $0.06 \times 3,410,000 = 204,000$ B.t.u. (11)

The rest of the losses are found in the energy of the condensed steam, in the cooling water, in the friction loss in the turbine, in the heat convection and radiation from the turbine case, and in the condenser, piping, etc.

These losses thus amount to $14,550,000 - 204,600 = 14,345,400$ B.t.u. (12)

The temperature of the condensed steam at 28.4 in. vacuum, or 0.75 pounds abs. pressure, is, as seen from steam tables, 92.5° F. It is evident from our previous calculations that the exhaust is not superheated, but contains in reality about 8.6 per cent. moisture, the actual moisture being less than that corresponding to adiabatic expansion on account of the re-evaporation of a part of the moisture by the heat caused by the rotation loss of the turbine wheels.

Since the combined efficiency of the turbine unit including the generator is assumed as 65 per cent. and as in all probability the generator has an efficiency of about 96 per cent., it is evident that the turbine efficiency is 67.8 per cent. The loss is largely all converted into heat and thus while the available energy is 290,000 ft. lbs. per lb. of steam, 32.2 per cent. is partially wasted as heat; that is, $322 \times 290,000 = 93,500$ ft. lbs., or 120 B.t.u. Considering, for simplicity's sake, that all work was done in one single pressure stage or turbine, then the pressure in the stage would be 0.75 lbs. The latent heat at that pressure is 1050 B.t.u.; thus 120 B.t.u. evaporate 11.4 per cent. of the moisture and we obtain the value, 20 per cent—11.4 per cent., or 8.6 per cent. as given above.

In returning the condensed steam to the boiler its temperature will drop slightly, due to conduction and radiation. This drop may be 7.5° F. The returned liquid heat of the water corresponds therefore to a temperature of 85° F. and is 53.06 B.t.u. Thus the total heat returned in the feed water is $53.06 \times 14,100 = 750,000$ B.t.u. (14)

The heat lost in the feed water is obviously

$7.5 \times 14,100 = 105,800$ B.t.u. (15)

Since the condensed steam at 92.5° F. contains as liquid heat $60.7 \times 14,100 = 855,800$ B.t.u., it is evident that the cooling water contains $14,345,400 - 855,800 = 13,489,600$ B.t.u.

As the steam goes from the boiler to the turbine there is a loss of heat which will be found as a drop in superheat. This might be 50° F. so that the steam as it leaves the boiler has a superheat of 200° F. This loss in heat then represents

$50 \times 0.5 \times 14,100 = 352,500$ B.t.u. (17)

The boiler must therefore supply—

$17,960,000 + 352,500 = 18,312,500$ B.t.u. (18)

Through the return of the feed water, however, we get 750,000 B.t.u.; thus the necessary coal corresponds to 17,562,500 B.t.u.

At a boiler efficiency of 80 per cent. this means that $\frac{17,562,500}{.80} = 21,953,000$ B.t.u. (20)

of coal must be supplied corresponding to an amount of 1690 lbs. per hr., or $\frac{21,953,000}{1,000 \times 13,000} = 1.69$ lbs. of coal per kw. hr. with coal containing 13,000 B.t.u. per lb. (21)

Heat Balance	B. T. U.	Per Cent
Boiler plant loss	4,390,500	20.0
High press. steam pipe loss	352,500	1.6
Rotation losses, gen.	204,000	.9
Electrical output, gen.	3,410,000	15.6
Cooling water loss	13,489,600	61.4
Heat lost in feed water	105,800	.5
Total	21,953,000	100.0

NOTES ON THE RELATIVE ECONOMY OF STEAM HEATING FROM AN INDEPENDENT LOW PRESSURE STEAM BOILER AND FROM THE EXHAUST OF THE STEAM TURBINE

PART II

To get some practical basis for comparison, it will be assumed that 1,000 kw. in electric power is wanted and that this power can be obtained from the turbine, even if it is operating non-condensing with a back pressure of 10 lbs.; that is, at an absolute pressure of 24.7 lbs. It will be assumed, as in the preceding case, that the initial pressure is 200 lbs. absolute and the superheat at the turbine, 150° F.; the combined efficiency of the turbine and generator being taken as 64 per cent. This efficiency is lower than that assumed in the first case, since the turbine losses due to rotation are greater. From equations (1) and (4) the following values are obtained:

$p_1 = 200$
$p_2 = 24.7$
$H_1 = 1198.3$
$C_p = .5.$
$T_2 = 239.5 + 460 = 699.5$
$T_1 = 381.6 + 460 = 841.6$
$t_1 = 150.$
$r_1 = 843.4$
$r_2 = 946.5$
$\phi_1 = .5429$
$\phi_2 = .353$

Substituting these values in (4) and (1) we get $x_2 = 0.94$ and $E = 137,600$ ft. lbs. per lb. of steam.

Thus the theoretical water rate is $\frac{2,654,000}{137,600} = 19.3$ and the actual water rate is $\frac{19.3}{.64} = 30.2$ lb. per hour.

With 1,000 kw. output, the flow is thus 30,200 lb. per hour. The total heat input is $1273.3 \times 30,200 = 38,454,000$ B.t.u. and the electrical output is 3,410,000 B.t.u. Thus the energy not converted into electrical energy is 35,044,000 B.t.u., or 91.2 per cent.

In carrying the investigation farther we will assume that the same percentage loss by various inefficiencies not connected with the steam part is 6 per cent = 204,600 B.t.u., and the remaining losses are therefore 34,839,400 B.t.u. This energy is available for steam heating and for heating the feed water. It may be assumed that the condensed steam returns from the radiators at a temperature of 85° F. and that this water is fed to the boilers. The liquid heat at this temperature is 53.06; thus the heat returned is $53.06 \times 30,200 = 1,602,400$ B.t.u., and the heat used for heating is:

$$34,839,400 - 1,602,400 = 33,237,000 \text{ B.t.u.}$$

To complete the heat balance, we may assume as before a drop in temperature of the superheated steam of 50° F., corresponding to 755,000 B.t.u. The boiler must thus produce 38,454,000 + 755,000 (the returned heat), or 37,606,600 B.t.u. With the boiler efficiency of 80 per cent., this corresponds to 47,008,200 B.t.u. from the coal, or with coal at 13,000 B.t.u. per pound, 3,616 lbs. of coal per hour for 1,000 kw. electrical output and 33,237,000 B.t.u. for steam heating.

If, instead of using exhaust steam, the turbine was run condensing and a special low pressure boiler of 24.7 lbs. abs. pressure supplied the steam required for heating, we would get the heat balance shown in second table following: assuming, as in the previous case, that 33,237,000 B.t.u. is needed for steam heating and 1,000 kw. electric power is obtained from a turbine operating with an initial pressure of 200 lbs. abs., 28.4 in. vacuum, and 150° F. superheat. It will also be assumed that the condensed steam from the heating system is returned to the low pressure boiler at 85° F. We then have: B.t.u. required for heating = 33,237,000; B.t.u. required from coal at 80 per cent. boiler efficiency = 41,546,200. In other words, with coal of 13,000 B.t.u. per lb., 3,196 lbs. per hour is required for heating purposes.

Heat Balance	B. T. U.	Per Cent.
Loss in boiler	9,401,600	20.0
Loss in steam pipes . .	753,000	1.6
Loss in radiation, etc. .	204,600	.4
Electric energy . . .	3,410,000	7.2
Heating purposes . . .	33,327,000	70.8
Total	47,008,200	100.0

Heat Balance for Low Pressure Boiler	B. T. U.	Per Cent.
Heating	33,237,000	80
Loss in boiler . . .	8,309,200	20
Total .	41,546,200	100

The coal required for one hour for heating by independent boiler and for furnishing 1,000 kw. from condensing turbine is, therefore, 3,196 + 1,690 = 4,886 lbs. per hour.

In comparing the two systems we have: For steam heating from turbine exhaust and 1,000 kw. electrical energy, 3,616 lbs. of coal per hour; and for steam heating from independent boiler and 1,000 kw. supplied by separate condensing turbine, 4,886 lbs. of coal per hour. In other words there is a saving by the first method of 1,270 lbs. of coal per hour, or 26 per cent. Incidentally, it is necessary to note that if all the coal required for steam heating in the second case is charged up to heating in the first case, we find that the coal required for electric power is only 3,616 − 3,196 = 420 lbs., or 0.42 lb. per kw. hr. This is but 24.8 per cent. of the coal required for the generation of electric power, even under the most favorable conditions of superheat and vacuum.

The calculations emphasize the desirability of steam heating from the exhaust steam and show numerically the magnitude of the gain.

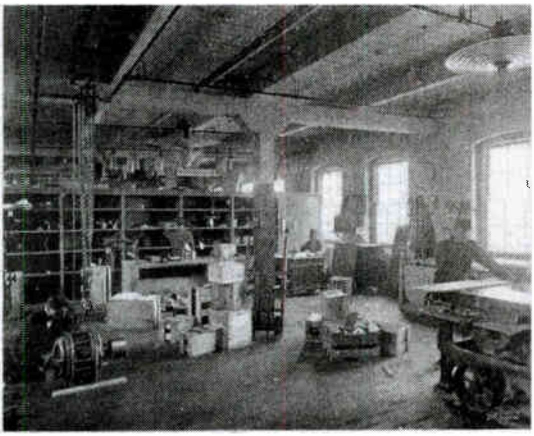
GENERAL ELECTRIC REPAIR SHOP AND WAREHOUSE CHICAGO, ILL.

By John Liston

As a rule, modern electrical machinery and auxiliary apparatus are properly designed, are constructed of good materials, and embody a high standard of mechanical and electrical efficiency. Under normal conditions, uninterrupted service may be depended on, and protective devices insure immunity from injury due to overloads or temporary strains on the distribution system. Those parts subject to excessive wear can generally be easily replaced, and the average electrical installation is usually provided with a certain amount of reserve machinery which can be set up promptly if the regular equipment is injured.

Due to long continued service, excessive overloading or accidents, persons in charge of installations of any size are sooner or later confronted with the necessity of repairing portions of the equipment which are of vital importance and on which the necessary repair and replacement work cannot be properly done without experienced workmen and a suitable mechanical equipment.

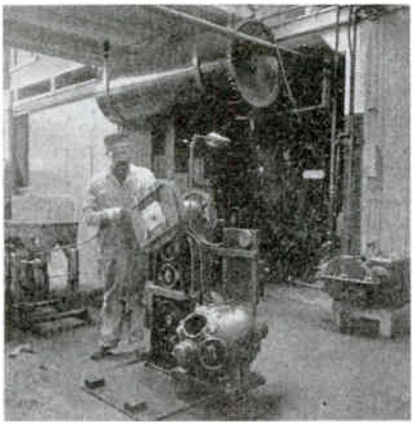
Transformer and Regulator Repairing and Testing. South Bay



Receiving and Storage of Parts

The construction of electrical machinery involves the use of special tools and must be supplemented by thorough testing. When repairs have to be made, the necessary operation can be most efficiently performed in a shop equipped solely for that class of work; having available, in addition, the services of men who are specialists in repair work and who have the necessary facilities and experience for making those mechanical and electrical tests which are essential in obtaining reliability in the future operation of repaired apparatus.

It is evident that a plant so equipped, and with a record of many years of successful work in the repair of all classes of apparatus, can effect repairs more promptly and economically than the average shop, where the repair department is considered merely as an auxiliary and in which the cost of the special machinery required would not be justified by the value of the limited service ordinarily performed in repair work. It will therefore be of interest to all users of electrical apparatus in or near the city of Chicago to note the thoroughness with which the General Electric repair shop has been equipped, in order to handle promptly all classes of electrical repair work.



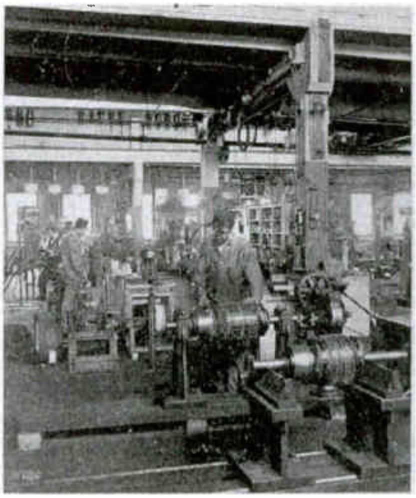
Winding a Field Coil in Repair Shop

The repair shop is located in the Pugh terminal warehouse, which is the largest building of its kind in the world, being six stories in height, 1800 feet long, and of heavy mill construction throughout. It is located on the north pier facing the slip, and therefore has ready access to the lighterage facilities of the Chicago river. Three tracks of the Chicago & Northwestern Railroad run parallel to the building on one side for its entire length, while the basement contains a terminal of the Illinois Underground Railroad; thus ample facilities are available for receiving and shipping apparatus.

Two sections of this building having a total floor space of 155,000 square feet are occupied by the General Electric repair shop warehouse. The repair shop occupies the top floor and has a saw-tooth roof, which insures excellent lighting conditions by day, while numerous arc and incandescent lamps are provided to give ample illumination for night work.

The repair work handled in this shop covers all forms of electrical apparatus which have been built during the last twenty years, the larger part of which consists of generators, turbines, motors, motor-generator sets, rotary converters, railway apparatus, rheostats, controllers, compensators, current and potential transformers, regulators, meters and instruments, arc lamps, heating and cooking devices, mercury arc rectifiers, switch and panel boards and electrical supplies.

About sixty men are constantly employed and approximately twenty of these devote a large part of their time to outside repair, testing and construction work. Many of these men have given their time exclusively to repair work for a number of years, having had a variety of experience that renders them qualified experts in this line. Their knowledge of apparatus is not confined to that manufactured by the General Electric Company, but extends to types of

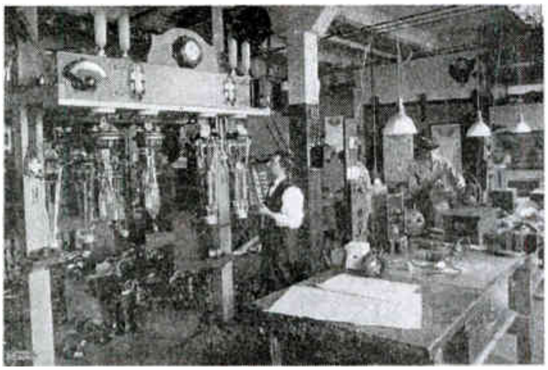


General View of Repair Shop

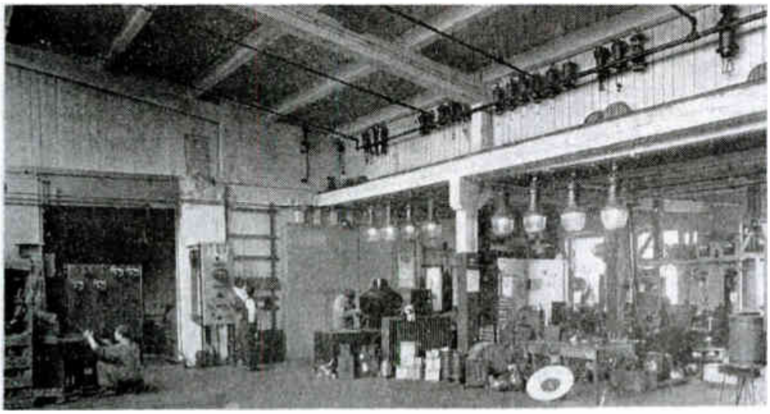
electrical machinery as built by practically all makers of electrical apparatus whose products have been on the market for the past twenty years. This fact is made evident by an inspection of the armature winding section of the shop, in which may be seen a variety of armatures of different types and date of manufacture from that of the old bi-polar Edison machines to the latest form of polyphase induction motors and generators. The advantage of having this class of labor to draw upon for the repair of machinery which is too bulky to be readily shipped to the repair shop, or for installation and repair work which can be easily done on the premises, is obvious, and as the men are divided into groups, each group confining its efforts to one particular line of work, an expert best suited for any given condition can usually be sent at once upon receipt of a customer's request.

It frequently happens that before deciding on the type of apparatus for a particular installation, a customer considers it advisable to observe the operation of different makes or types of machine in actual service. These can be temporarily installed in the testing section of the repair shop and their performance noted and compared.

In order to provide current for testing different classes of apparatus, this section of the repair shop is provided with a very complete machine equipment. Direct current is received from the Commonwealth Edison Company's lines at 220 volts, and by means of motor generator sets direct current at 125, 250 and 500 volts is obtained. Alternating current at frequencies of 25, 60



Arc Lamp and Fan Motor Repairing and Testing

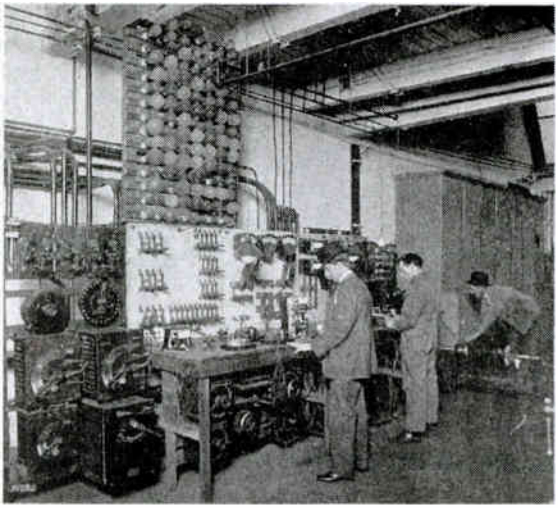


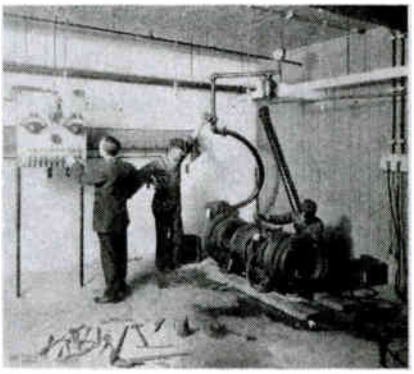
Multiple and Series Rectifier Tempering Furnaces and 125 cycles, and 110, 220, 440 and 2200 volts is also available.

For high potential tests, transformers are provided which step up to 50,000 volts and constant current transformers and regulators are also installed for arc lamp and regulator testing. The testing equipment includes a main switchboard and a switchboard for instruments and meter testing, suitable for instruments up to 3000 amperes capacity direct current and all frequencies and capacities alternating current. Special switchboards are used for arc lamp testing and for cooking and heating apparatus.

The re-winding of armatures constitutes a large proportion of the work done, and an expert crew of armature winders is always retained exclusively for getting out work of this kind on short notice. Form wound coils for standard machines are held in stock, and forms suitable for winding every variety of field coils are kept on hand. The machines for field winding and for banding armatures are motor driven and capable of handling work for any size armature up to six feet in diameter.

The winding benches are served by monorail cranes, and the two main bays of the repair shop are provided with 5-ton motor driven cranes.


Meter and Instrument Testing Board


Steam Turbine Section

In the arc lamp section, rectifier sets, charging outfits, headlights and searchlight projectors of any size are repaired and refinished. The equipment includes an electric oil tempering furnace, and compressed air for brazing and cleaning is supplied by a standard General Electric motor-driven air compressor set.

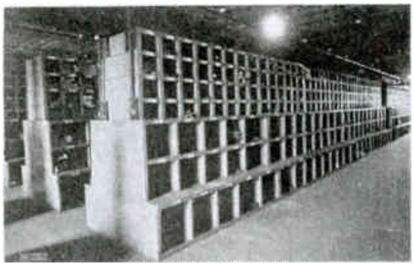
A separate section of the repair shop is devoted to the testing of steam turbine generator sets and ample boiler capacity is available for sizes up to 100 kw.

Warehouse

In order to facilitate the prompt shipment of all standard apparatus, the General Electric Company has established in this building a completely stocked warehouse, from which shipments varying from 25 to 30 car loads per day are sent. The extent of the available stock is indicated by the following statements:

Incandescent Lamps in Warehouse

Under normal conditions there are on hand never less than 1500 power motors of all capacities up to 150 h.p., and about 10,000 fan motors. There is a very complete stock of wiring material, including sockets, receptacles, cleats, etc., together with rubber covered and weatherproof wire and overhead railway line material. There are approximately two million incandescent lamps boxed for immediate shipment, and various types of arc lamps for all commercial circuits. Current and potential lighting and power transformers are kept in sizes up to 50 kw., and a reserve supply of 5000 gallons of transformer oil is also maintained. The stock includes rectifier outfits for both lighting and battery charging and a complete line of heating and cooking devices.



Steel Bins for Loose Stock

For the storage of broken stock, such as instruments, heating and cooking apparatus, supply parts, etc., 4700 bins are used; nearly all of these are made of steel.

The heavy construction of the building makes it entirely safe to store the great quantity of relatively heavy apparatus, and an overhead motor driven monorail crane facilitates the storing of material and handling it for shipment.

The tunnel of the Illinois underground railroad runs the entire length of the building, and the railroad tracks of the Chicago & Northwestern railroad, located along the side of the building, provide rail space for 21 cars. About 50 men are employed in the warehouse, from which a large percentage of the less-than-carload shipments of General Electric apparatus in the Chicago territory are made.

ELECTRICALLY DRIVEN PORTABLE ELEVATORS AND CONVEYANCES

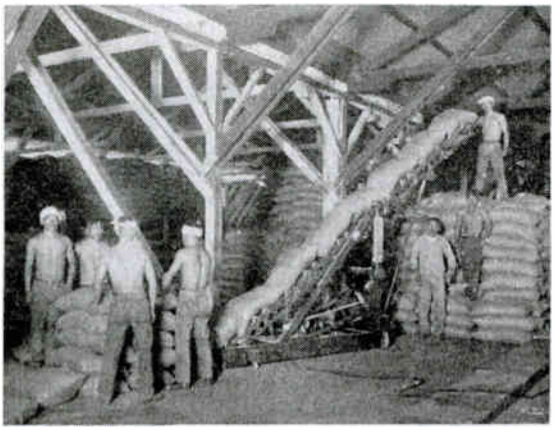


Fig. 1. Brown Portable Sack Elevator, Driven by 2 H.P. General Electric Motor Capacity, Twelve to Fourteen 150 lb. Sacks per Minute

Wherever it is necessary to handle large quantities of those commodities which are ordinarily transported in bales, sacks, boxes, barrels, etc., it is of prime importance that the work be done quickly and cheaply, especially in localities where labor is scarce or expensive.

Even in those localities where the cost of labor is a minimum, the accomplishment of this work by means of a motor driven portable elevator will still effect a large saving, although the cost of electric power be unusually high. The conditions which exist in the larger agricultural areas and storage centers of the country impose the necessity for very efficient transportation and handling facilities and have resulted in the invention and manufacture of some exceedingly valuable motor driven machinery for replacing the comparatively slow, unreliable and expensive handling by manual labor.

In the General Electric Review for May, 1908, an article was published descriptive of two electrically driven portable elevators manufactured by the Brown Portable Elevator Co., Portland, Oregon. Additions have recently been made to this Company's line of elevators and conveying machines, which include a number of refinements in the matter of design, operation, etc., that will warrant an additional description in these pages.

Fig. 1 shows a Brown portable sack elevator having a capacity for piling from 12 to 14 150 lb. sacks per minute. This machine is driven by a General Electric 2 h.p. direct current motor, through a jack shaft and double belt. This motor is shown mounted on a movable base frame, which also carries

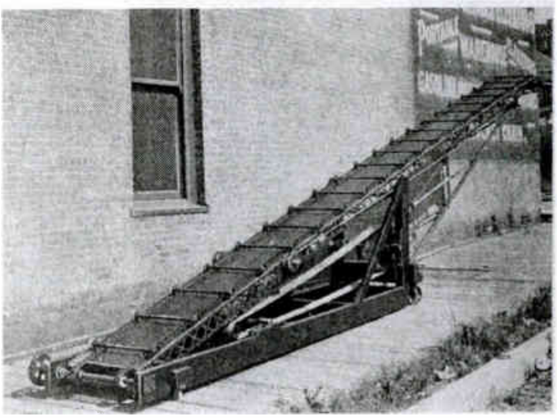


Fig. 2. Brown 5 Ton Standard Conveyor, Driven by General Electric Motor

the runway or conveyor platform and the necessary steel cables and winch head by means of which the height of the delivery platform may be varied.

Fig. 2 shows very clearly the general design of the Brown standard 5 ton conveyor. As will be seen, the main driving sprocket is keyed to a shaft upon which are mounted 2 small sprockets engaging two parallel chains, these chains supporting at intervals axles carrying small wheels which run on rails fastened to the steel lattice work forming the sides of the runway.

All these elevators are fitted with ball bearing castors which permit of ready transportation of the apparatus from place to place. Since the winch permits the carrier to be easily raised, the material which is being elevated may be delivered at any desired height.

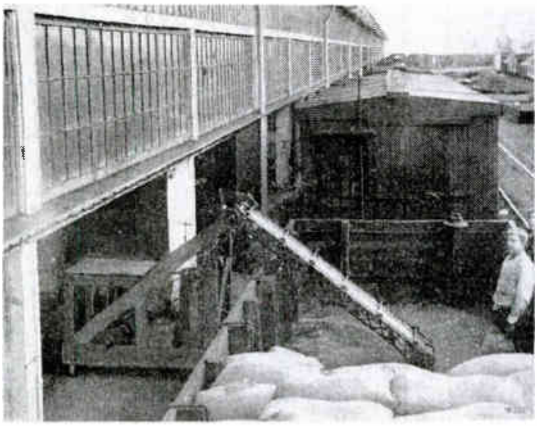


Fig. 4. Brown Portable Elevator for Unloading Gondola Cars

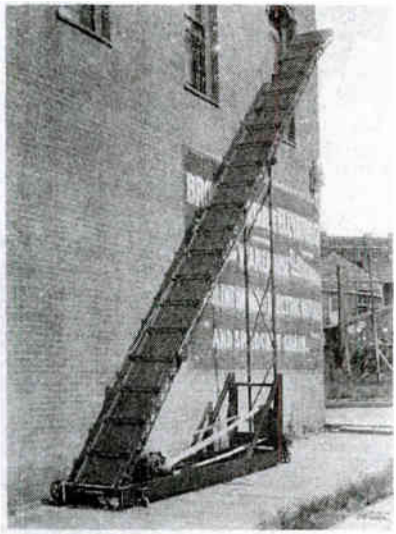


Fig. 3. Brown Portable Elevator with Extra Long Conveyor Platform

The success which has attended the use of the sack elevator encouraged the manufacturers to develop a similar machine for elevating baled hay, straw, fodder, etc. This machine is shown in Fig. 3 and differs from its prototype (Fig. 1) only in that the conveyor platform is longer, this being necessary since bales are often piled to a height of from 30 to 35 ft. This elevator will raise from one to three tons of baled material per minute, and will serve equally well for the handling of produce in sacks.

In the agricultural districts of the country, grain is shipped largely in open gondola cars. For loading or unloading such cars, the portable conveyor shown in Fig. 4 is used, the runway of which may be operated in either direction by simply reversing the direction of rotation of the driving motor.

Brown portable elevators of the latest models are now made in a variety of sizes and types, the smallest of which weighs 900 lbs. and is driven by a 2 h.p. motor. This machine has a maximum rise of runway of 14 ft. and a capacity of one ton per minute. The largest standard size (Fig. 2) is equipped with a 5 h.p. motor and will lift 5 tons per minute to a height of 25 ft. Special machines are built to order.

The profit to be derived from the use of the Brown portable elevators is shown by the following example:

To pile 300 tons of sacked grain in one day requires the services of 15 men, assuming that each man can handle 20 tons per day. At a wage rate of $2.00 per man per day, the labor cost is therefore 10 cents per ton, or $30.00 per day. The same work when performed by a Brown portable elevator will cost, with current at 5 cents per kw. hour, approximately as follows:

Electric energy for 3 h.p. motor operating at 50 per cent. load factor 10 hours per day	$1.35
Three men at $2.00 per day . . .	6.00
Total	$7.35
Net saving per day	$22.65

This saving might be materially increased if the elevator were operated at its maximum capacity of 7,000 sacks per day, or approximately 525 tons.

Brown portable elevators were originally designed to be driven by internal combustion engines, and in certain sections of the country where electric power is still unavailable, these engines are used. However, where electric power can be had, the electric motor is naturally the preferable form of drive, owing to its greater reliability, simplicity and facility of control, and to the reduced fire risk resulting from its use.

SOME CONSIDERATIONS AS TO THE NATURE OF COMETS AND THEIR PROBABLE RELATION TO THE SUN*

By Prof. Elihu Thomson

The ideas herein put forward are not all original with the author, though it is believed some of them may be. It is hoped that the considerations may, however, help to a simple rational understanding of the major facts regarding the behavior of comets.

The exceedingly high temperature of the sun causes it to be surrounded by an atmosphere of vapors. Some of the vaporized matter condenses in the outermost layers and eruptions are constantly occurring which partly fill the space around it with very fine particles, the smaller of which are repelled by the pressure of the sun's radiation, which pressure even overcomes the gravitative force of the sun itself. These ejected particles probably constitute the streamers which are visible during total eclipses as extending outwardly from the sun to immense distances. What we see is the effect of innumerable overlapping streams. Their extreme tenuity is evidenced by the comparatively feeble luminosity, in spite of the great depth of the flux which we are at any time observing. This depth is, of course, greater than the diameter of the sun. Such corona streamers are by no means uniformly distributed about the sun, but in certain directions—varying continually—may be more dense than in others, coinciding perhaps with great eruptive areas of the sun's surface. It probably happens that when the outbreak is unusually violent, and when the earth happens to be passing through that part of space occupied by an abnormally extended streamer, an aurora of greater or lesser intensity or duration may attend the sweeping of the earth by such a streamer. The particles are probably ions, or carry electric charges, and induced auroral streamers in the earth's atmosphere are for the time being visible on its dark side away from the sun.

It has been thought that comets may act in a somewhat similar way to disclose the condition of the ejected material of the sun, or, as may be conceived, to disclose a stratification or unevenness of distribution of the ejected matter from the sun. Since there is reason to believe that much of this matter is in a highly electrified state, it is not to be doubted that electrical phenomena are at the same time produced, with accompanying evolution of light. Indeed, in the free space around the sun, there must be a great intensity of ultra violet radiation, which of itself would cause emission of negative ions from matter in its path and produce electrical disturbances. But, aside from this possibility, the comet is recognized as an assemblage of particles, larger or smaller, moving in an orbit which involves great variations of its distance from the

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sun. In passing through the depths of space far away from the sun, these parts or particles may tend, by their feeble gravitative effect, to gather up any finer particles which, on account of the intense cold of space, are substantially solid, even though at ordinary temperatures they would be gaseous. The parts of the comet's nucleus more or less porous would, in this way, accumulate upon their surfaces and in their pores occluded gases, condensed material and fine dust; and there would be a period of many years in which this gathering up process, as in the case of Donati's and other long period comets, would occur.

Let a comet, as an assemblage of such small masses, after its long course through remote space, during which it has gathered fine particles ejected from the sun or from other bodies, reach, in approaching the sun, a part of its orbit where the temperature, given by the solar radiation to the surfaces of the masses, is sufficient to boil off or regasify the condensed material; then not only is the gas blown off into vacuous space around the nucleus of the comet, but it is naturally blown off in the direction towards the sun, from the heated side of each mass, and at the same time that the gas leaves the mass, other fine particles are lifted by the force of the escaping gas. This is due to the fact that these fine or dust-like particles are not held with any strong gravitative tendency. Ultra violet radiation may also add its effect in causing discharge of negative ions. The result of this is that jets or flows of materials from the nucleus tend into the vacuum towards the sun from the warmed or radiation absorbing surfaces of the comet's nuclear masses. As soon as they leave the nucleus or the warmed surfaces, they are again cold and mainly condensed. But though exceedingly fine they are now absorbers, more or less solid, of the sun's radiation, and are gradually thrust backward by the pressure of the light and radiation, and are blown off in the opposite direction by this pressure, so forming a tail in the contrary direction from the sun, or in a direction opposite to that in which they were first ejected.

There being in matter all grades of volatility, as the cometary body approaches the sun, material more and more refractory, so-to-speak, is evolved, until finally, if the approach is near enough to the sun, even ordinarily solid substances will be vaporized from the nuclear masses and projected to form a tail, as has just been described. Some of this vaporized matter will immediately condense on getting a little farther away and form solid particles in the tail. The comet of January, 1910, showed sodium lines, showing that the temperature of the nuclear masses had probably reached the vaporization point of sodium. The greatest extension of a comet's tail usually comes just after the comet passes perihelion, because the heating process keeps on, as it were, a little past perihelion; just as the hottest parts of our summer days are two or three o'clock in the afternoon.

Now, if the comet stays in proximity to the sun long enough, it will have discharged nearly all of its volatile material for a particular temperature reached. But on leaving the sun after the tail has shrunk, (which is a very natural thing for it to do when the body passes through regions less heated by solar rays), it may again be in the condition to gather up the condensed and practically solid gases and vapors in the space around it. And if its period is a long one, such as 2000 years, as in the case of Donati's comet, it should not surprise us if there is sufficient material to form a fair tail, which only lasts a few weeks at the most.

Then it must be borne in mind, too, that an extremely small amount of material diffused in space under solar radiation will suffice to form a very large tail, as every particle, even of extremely small mass, becomes substantially a light source. Take for instance the amount of tobacco smoke that can cloud up a room when the sun is shining in it, and it will be found to be a very small quantity; but, if the room be black as night, and a hole be made in a shutter through which a small beam of sunlight enters, and the minutest body of smoke be diffused in the room, there will be a "comet's tail" extending from the opening across the room where the sunbeam passes, because it will be seen in the blackness, and that is the condition of our seeing comets' tails in the darkness of night. Then we must remember how deep the space is which is occupied as a visible thickness in a comet's tail, say 150,000 miles. We thus get an idea of how *free* of particles space must be *not* to shine with a luminosity equal to that of a comet's tail when we look off into the dark night irradiated by the intense solar beams.

Doubtless the simple view here given is complicated by many other actions, electric, etc. Comets' tails sometimes vary greatly and rapidly. We need not be surprised at this when boiling points are known to be critical; when, in other words, a few degrees increase in temperature may vaporize a substance which would not otherwise have been vaporized. Furthermore, it is quite possible that the comet in moving around the sun, entangles itself in the stream of material driven from the sun, and varies in its effect in accordance with its being or not being in a solar streamer more or less dense for the time being, speaking relatively. It is easily conceivable that an assumed stratification of space may be a cause of variations of comets' tail brightness. Putting it properly, it is conceivable that a comet may act as an indicator of the condition of space around the sun, the space in which the comet, for the time being, is moving. Even under the idea that there is volatile matter emitted from the sun which ordinarily would not be visible, let such matter strike into the nucleus of a comet and meet matter from the comet itself, it is easily seen that interactions, electrical or otherwise, or even physical collisions, may add to the light of a comet's tail.

The chief point, however, which I have endeavored to emphasize by the comparisons above made, is the excessive tenuity of the matter which would be sufficient to give rise to a brilliant appendage to a comet, and the exceedingly small amount of volatile matter needed. This fact renders it possible that the comet may, in the lapse of many years, replenish itself in the depths of space and may account for the fact that at each return to close proximity to the sun, a tail is developed. Otherwise, since the matter of the tail certainly does not return to the comet, it would seem that the volatile matter would be distilled off and lost in very few perihelion passages.

In regard to the predicted sweep of the earth by the tail of Halley's Comet on May 18th, it is evident from the accounts that have been received that such passage of the earth through the comet's tail did not occur on time. It was evidently more gradual than was anticipated and was delayed for two or three days. This is not to be wondered at, for the reason that in viewing a comet like Halley's, the orbit lies in the general plane of the earth's orbit, or not many degrees inclined thereto. We see the tail straight, although if we could see it from a position at right angles it might be heavily curved. Theoretically, the material which forms the tail, having been expelled from the nucleus and driven backward, the portions of the tail farthest from the comet would naturally correspond to positions of the comet farther back in its orbit; hence the stream of material would have a bend backward as the comet advances. Not only is this the case, but from the fact that without doubt the material of the tail consists of particles of varying size and density which would be repelled backward at different velocities, the curvature would vary with the size and velocity of the particles expelled, which would have the effect of broadening out or fanning out the tail into a sort of curved fan-like appendage in the plane of its orbit, or making multiple tails. From our position this would be impossible to observe, but it would account for the apparent fact that the earth took a considerable time to traverse this broadened out tail bent strongly backward. This would also account for the fact that parts of the tail might be seen in the east even after the nucleus had passed the sun, and would also explain why parts of the tail were seen in the west while there was an appearance of some of the remaining material of the tail in the east. In such case, the earth would really be in the position of passing through the spread out curved tail and the passage might take two or three days.

At the present writing, May 26th, the tail of Halley's Comet is completely seen in the west after sunset, and is apparently straight, which, of course, is due to a line of vision coinciding nearly with its direction of recession. The telescope shows the nucleus to be of only moderate size, a few hundred miles in diameter at the most, and that in the direction towards the sun there is a great emanation of matter which is luminous and which forms a bright cloud for a considerable distance around the nucleus on the side towards the sun. This is, however, seen to bend backward and apparently form the elongated tail which expands for many degrees away from the sun and has a very considerable breadth.

DISTRIBUTION OF ELECTRIC ENERGY TO INTERURBAN POINTS FROM A SMALL CENTRAL STATION

AS EXEMPLIFIED BY THE HILLSBORO ELECTRIC LIGHT AND POWER COMPANY

By C. R. Croninger

The Hillsboro Electric Light and Power Company, of Hillsboro, Ill., capitalized at $63,000 and bonded for $12,000, furnishes electric current to the towns of Hillsboro, Coffeen, Irving, Witt, Raymond and Harvel, all situated within a radius of 20 miles from the power house at Hillsboro and possessing a total population of 8700 inhabitants. The property held by the Company represents a total investment of about $92,400, and the gross receipts for the year 1909 were $42,707.19.

The transmission lines supplying these towns have an aggregate length of about 40 miles and some 160 kw. in stepdown transformers is connected thereto. The diagram and accompanying data on the following page have been prepared to show the arrangement of the lines and to give concise information relating to the several installations: length and cost of lines, cost of substations and apparatus, number of customers (lighting or power specified), number and sizes of motors, etc., etc., are given.

The lines are fed from a 90 kw. engine-driven single-phase alternator, through two 75 kw. transformers; this apparatus, together with a spare alternator of 200 kw. capacity and a 35 kw. constant current transformer, being located in the power house at Hillsboro. This constant current transformer supplies current to 38 arc and 33 75-watt series incandescent lamps for lighting the streets of Hillsboro; the multiple incandescent lighting system of this town receiving its current direct from the alternator bus bars at 1100 volts. Thus it is seen that apparatus with a total rated capacity of more than 185 kw. is directly supplied with current from the one 90 kw. generator—a fact that is interesting and perhaps somewhat surprising.

Current is generated at a potential of 1100 volts and is delivered to the transmission lines at 16,500 volts. At the receiving ends of the lines, the voltage is stepped down to 2300, at which potential the local distribution systems are supplied. Current for Harvel is obtained at a potential of 2300 volts from the secondary windings of the transformers at Raymond, distant four miles.

The transmission lines, with the exception of the one from Hillsboro to Coffeen, are all of No. 8 B.&S. hard drawn copper wire strung on wooden poles; the line to Coffeen being of No. 6 copper wire strung on 30 ft. white cedar poles with 6 in. tops. In future the Company will construct all new lines of No. 6 B.&S. wire or larger; in fact, it has seriously considered the adoption of No. 4 B.&S. as standard.

The average cost per mile for all lines was $353.22. The total cost of the Coffeen line was $5,145.00, made up as follows:

1⅓ miles 40 ft. pole line in town	$690.00	
Labor on same	204.00	
6⅓ miles 30 ft. pole in country	1826.00	
Labor on same	468.00	
		$3188.00
Substation at Coffeen	$400.00	
2—50 kw. transformers	900.00	
1—Lightning arrester	180.00	
1—Wooley arrester	107.00	
1—Switchboard	140.00	
1—Time switch	45.00	
		1872.00
Trees bought	$52.00	
Private right of way	33.00	
		85.00
Total cost of line		$5145.00

The Coffeen line is the most modern of all the lines, and although the others were constructed along public highways under permit of the County Board, the Company believed that it would be to its advantage to construct this line over a private right of way. Upon investigation, it was found that this privilege could be secured at a cost of 35 cents per pole, and the necessary steps were taken to acquire the right of way.

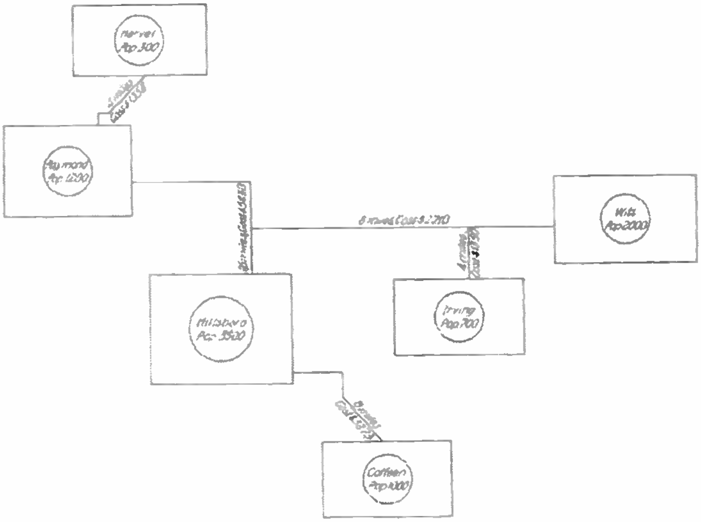
The Company has adopted a uniform system of rates, as follows:

Series arc lamps, 6.6 amps., all night moonlight schedule	$72.00 per yr.
Series Mazda lamps, 75 watt, 6.6 amps., all night moonlight schedule	24.00 per yr.

(Towns to renew lamps at own expense.)

Lighting, 15 cts. per kw-hr. for first 15 hours and 10 cts. per kw-hr. for all quantities in excess of this amount; minimum charge per meter per month, 50 cts.

Power, 6 cts. per kw-hr. maximum, and 3 cts. per kw-hr. minimum.



HILLSBORO

Capital stock, $63,000.
Bonds, $12,000.00. Distribution, $15,300.
Cost power plant, $27,120.
Coal, slack, $1.00 per ton delivered in bin.
Water, $0.03 M. gallons.
1- 90 kw., 60 cycle, 1100 volt single-phase generator.
1-200 kw., 60 cycle, 1100 volt single-phase generator.
2-75 kw., 1100/2200-16,300 volt stepup transformers.
1-35 kw., 6.6 amp. constant current transformer.
City contract. Schedule moonlt. all night.
38-6.6 arc lamps, $32 per year.
33-75 watt series inc. lamps, $24 per year.

Commercial customers	123
Residence customers	340
Power customers	12
Total customers	473

Motors connected 58½ h.p.

HARVEL

Cost of substation and distribution, $1976.
Receives 2300 volt current from Raymond.
City contract. Schedule, moonlt. all night.
27-75 watt series inc. lamps, $24 per year.

Commercial customers	12
Residence customers	33
Power customers	3
Total customers	48

1-33 h.p. motor. Brick and tile works.
1- 5 h.p. motor for blacksmith shop.
1- 5 h.p. motor for blacksmith shop.

RAYMOND

Cost substation and distribution, $6793.
1-40 kw., 1100/2200, 16,300 volt stepdown trnsfr.
1-12 kw., 66 amp. constant current transformer.
City contract. Schedule moonlt. all night.
17-6.6 amp. arc lamps, $75 per year.
12-75 watt series inc. lamps, $24 per year.

Commercial customers	36
Residence customers	65
Power	2
Total customers	103

1-30 h.p. motor. Elevator.
1-10 h.p. motor. Tile and cement plant.
Labor one man, $30 per month.

IRVING

Cost of substation and distribution, $1229.
1-20 kw., 1100/2200-16,300 volt transformer.
1- 4 kw., 4 amp. constant current transformer.
City contract. Schedule moonlt. all night.
29-75 watt series inc. lamps, $24 per year.

Commercial customers	14
Residence customers	46
Power customers	1
Total customers	61

1-10 h.p. motor. Feed store.

WITT

Cost of substation and distribution, $4,534.
1- 4 kw., 4 amp. constant current transformer.
1-30 kw., 1100/2200-16,300 volt stepdown transformer.
City contract. Schedule moonlt. all night.
25 watt series inc. lamps, $24 per year.

Commercial customers	35
Residence customers	73
Power customers	3
Total customers	111

1-30 h.p. motor. Elevator.
1- 3 h.p. motor. Blacksmith shop.
1- 3 h.p. motor. Baker.
Labor one man, $60 per month.

COFFEEN

Cost of substation and distribution, $7301.
1-30 kw., 1100/2200-16,300 volt stepdown transformer.
City contract. Schedule moonlt. all night.
18 multiple 5 amp. arc lamps, $72 per year.

Commercial customers	25
Residence customers	80
Power customers	2
Total customers	107

1-15 h.p. motor. Elevator.
1- 1 h.p. motor. Livery stable.
Labor one man, $15 per month.

Motors aggregating 150 h.p. are connected to the Company's lines in the various towns, and 50 per cent. of these by rating are employed for operating grain elevators that were formerly equipped with steam plants. This industry offers the most extensive and profitable field for the sale of power in small towns situated in this section of the country.

In connection with the electric power plant at Hillsboro, the Company has installed a 20 ton ice making machine and a system for steam heating. These three enterprises are carried on in one building, and the Company is therefore able to generate electric current at a very low cost per kw-hr.

At one time this Company sold current to the system at Witt, which was then operated by an independent concern, at the rate of 5 cents per kw-hr. for the first 2000 kw-hrs. per month, 4 cents for the next 2500 kw-hrs., and 3 cents for the balance. The Witt Company did not find this profitable business and therefore sold out to the Hillsboro Electric Light and Power Company, after which current was billed through the home office, as in the case of the other towns.

Time switches have been installed on the incandescent and series arc circuits in all the towns but Hillsboro, and ordinarily the attendant has no duties to perform for the Company other than to keep the switch wound. The total cost of inspecting the transmission lines and supervising the distribution in the five outlying towns is only $125.00 per month, or an average of $25.00 per town.

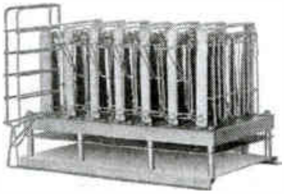
The total output, as recorded by meters on the switchboard at Hillsboro, when checked against the total current sold and accounted for, shows 28 per cent. loss in lines, transformers and meters.

When considering a plant of rather limited equipment, the question of reliability of service naturally arises. By a careful system of line inspection, the Hillsboro Company has been able to keep the interruption of service down to a minimum, and from the time when the transmission line was first put in operation (1905) to the present, there has been but one night when the towns were without current. The trouble on this occasion was caused by a defective insulator, but since that time double petticoat insulators designed to withstand 40,000 volts have been substituted for the old style ones and no further trouble of this kind has been experienced.

At present, three other neighboring towns, with a total population of 5000 people, are negotiating with the Hillsboro Electric Light and Power Company for service. One of these towns, the population of which is perhaps 2500, has a plant already installed, and at the rates quoted by the Hillsboro Company, the management believes that it will be more profitable to purchase current from the above concern than to generate it themselves, since their customers demand a 24 hour service. In this case, the Hillsboro Company will erect a transmission line at its own expense and will install a primary wattmeter in the customer's station, thereby assuming all line and transformer losses.

ELECTRIC TOASTER FOR HOTELS AND RESTAURANTS

The ordinary method of making toast by a coal or charcoal fire does not always produce satisfactory results, for when this work is to be done, it is often found that the live coals have been covered with a fresh supply of fuel, or else that the fire has burned out and is more or less covered with ashes. Hotels and restaurants are daily required to furnish large quantities of toast which must be prepared on short notice, and it is to the interest of all establishments of this nature to avoid conditions in its cuisine, such as the above, which are prone to result in dissatisfaction.



A six-slice toaster designed specially for hotels and restaurants has just been placed on the market by the General Electric Company. The use of this device insures warm, crisp toast, and the freedom from all soot, ashes, and delay in waiting for the fire to come up.

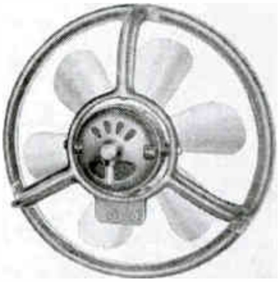
The operating units consist of vertical coils such as are used in the two-slice toaster, and the toasting is accomplished by means of radiant heat, the maximum temperature being almost instantly available when the current is turned on. It is not necessary to turn the slices of bread, as the heat acts upon both sides of each slice at the same time.

This larger toaster has a maximum capacity of six slices, each slice being placed in a hinged wire rack located between two rows of heating units. Each rack is provided with a wire handle projecting from the top edge, which, when depressed, swings the rack upward and out from between the units. There are thus seven rows of heating units, each row consuming 500 watts and consisting of four vertical heating elements. These rows are arranged in two sections, one of three rows and the other of four rows, it being possible to operate either section alone or in conjunction with the other. Thus two, three, or six slices of toast may be made at one time. The device will produce six slices of toast per minute.

SMALL VENTILATING OUTFITS

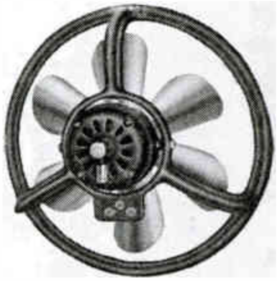
By R. E. Barker

To procure fresh air and to keep it in circulation is a problem of particular interest to those who are compelled to be either temporarily or permanently indoors. In summer especially, and in low and inland sections of the country, arrangements for good ventilating become a matter of business necessity in order to render a store, shop, or factory habitable during the hot months. Good ventilation is equally important where large numbers of people congregate, as in audience rooms, banquet halls, clubs, etc.



12-Inch Direct Current Ventilating Outfit

Where it is desirable to remove small quantities of air, the General Electric Company is prepared to furnish ventilating fan outfits, with either 12 or 16 inch fans, for alternating or direct current circuits of standard voltages and frequencies. These outfits are useful in offices, kitchens, dormitories, shops and stores, and are shipped complete

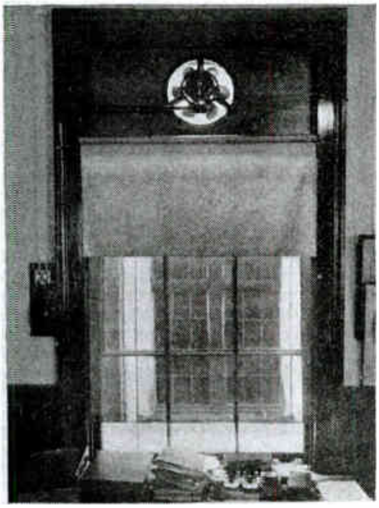


12-Inch Alternating Current Ventilating Outfit ready for operation, with motor, fan, and tripod. Speed controllers are included with the alternating current outfits and may be furnished as extras with the direct current outfits.

The sets are self contained, quiet in operation and comparatively small. Consisting, as they do, of a fan mounted on the same shaft with the motor armature, no power is lost as with a belt or other form of transmission. One of these outfits may be installed in a transom or window, and its operation controlled from any convenient point by means of the controller.

Fig. 1 illustrates a typical example of an up-to-date installation of a twelve inch alternating current outfit with combined starting and speed controlling device giving three speeds.

All of our larger cities afford a ready field for the use of the sets described, for ventilating hotel dining rooms, restaurants, cafes, kitchens, saloons, billiard parlors, business offices and accounting rooms, garment manufacturing and tailoring establishments, newspaper offices, job and book printers, binderies, laundries, dyeing houses, and paper, box and tobacco factories.



Installation of 12-Inch Alternating Current Ventilating Outfit

The alternating current motors are of the induction type, while the direct current motors are series wound. All these motors are fitted with six blade fans properly shaped to provide a good displacement of air.

Alternating current motors are offered for the usual commercial voltages, for 60, 40 and 25 cycle circuits, while the direct current motors are supplied for 110 and 220 volt circuits.

Combined Starting and Speed Controlling Box

The combined starting and speed controlling device, which forms a necessary part of the alternating current outfit, is built in a cast iron box similar to that used for the direct current controller. A substantial and attractive case contains the regulating reactance and indicating lever switch. This switch has four points and provides for three running speeds and an "off" position. The direct current controller contains a resistance made of a material which has unity temperature coefficient and which is permanent in character. Connections between the two devices are simple: one line wire runs to the motor and the other to the controller, the remaining connections being made between motor and controller—two leads for the alternating current and one lead for the direct current outfit. This arrangement permits the installation of the controller at any convenient place independent of the location of the motor.

By means of the controller the speed of the fans can be regulated to suit the conditions of the individual installations, such as quiet running, reduced air delivery, etc. A noteworthy feature of these motors is the reduction in the energy consumption with a reduction in speed, the energy required being approximately proportional to the speed.

These sets are carefully made and well finished. The best testimonial for these devices is the growing demand made for them by the public.

PRODUCER GAS POWER*

By C. L. Straub

The trend of feeling by the engineering fraternity toward gas power has undergone a marked change during as recent a period of time as the last five years. Five years ago gas power plants were installed by men who were classed among the profession as pioneers and visionaries; to-day it is only the uninformed engineer or promoter who contemplates the installation of a power plant without investigating the merits of gas power before making his decision, and rare indeed are the recent installations of power apparatus where the internal combustion engine has not had the weighty and careful consideration it merits.

Only six years ago I had an experience which illustrates the fact stated in my opening remark. I was a party to the sale of a 1400 h.p. gas engine that was to be used for the generation of street railway current. I enthusiastically wrote a literary friend, Mr. Henry Wallace Phillips, who spent his summers fighting with a small gasoline engine launch, advising him of the sale. He answered as follows: "When I learned that a man had bought a 1400 h.p. gas engine, I felt so bad I could have wept. I thought language ran out at about 10 h.p.; personally I find myself at a loss for words with 1½ h.p. on warm days."

It is an indisputable fact that through the persistent and tireless efforts of many capable men the internal combustion engine and its attendant gas producer have been brought to such a remarkable state of perfection that for economy and reliability of operation it has no superior. I know of a number of plants fitted with gas engines and producers where the operation is habitually on the basis of from 60 to 90 twenty-four-hour days per run, each engine carrying from 50 to 100 per cent. of its rated load and sometimes an overload; the units being shut down at regular intervals for inspection and minor adjustments, and again immediately cut into service on the weary grind. Among such plants may be mentioned the following:

American Smelting and Refining Co., Santa Barbara, Chi. Mex., where seven 300 h.p. American Crossley engines and down draft producers are installed.

Milwaukee Northern Railway, Port Washington, Wis., equipped with two 2000 h.p. Allis-Chalmers engines and down-draft producers.

Swift & Co., Bartow, Florida, equipped with three 250 h.p. Rathbun engines and down-draft producers.

Iola Portland Cement Co., Dallas, Texas, equipped with four 1100 h.p. Snow engines and down-draft producers.

American Bridge Co., Pencoyd, Pa., equipped with one 400 h.p. Snow engine and up-draft producer.

Messrs. Crossley Brothers, Manchester, England, point with well deserved pride to one of their 300 h.p. engines which operated on producer gas carrying from 20 to 100 per cent. of rated load for a solid year of 365 twenty-four-hour days, without a single shut-down in that time. I have never heard of any other form of prime mover but a water wheel, if that may be considered as a prime mover, that came anywhere near this record.

The question of fuel consumption in producer gas power plants is a much mooted one. I beg to submit a few authentic records.

Boston Elevated Railway Co., Sommerville, Mass., equipped with:

Two single acting double cylinder horizontal American Crossley engines. 750 h.p. each. Engines direct connected to 550 volt direct current generators.

One 1500 h.p. down-draft bituminous gas generating plant operating on West Virginia coal. The service is 20 hours run daily with one engine in service all day, the other engine in service during the morning and evening peak loads.

One 30 day commercial test showed 1.31 lbs. of fuel per kilowatt hour on the switchboard; one 60 day commercial test showed 1.34 lbs. per kilowatt hour on the switchboard; one 90 day commercial test showed 1.42 lbs. of fuel per kilowatt hour on the switchboard; and one year's record, on the basis of less than 20 per cent. station load factor, showed 1.66 lbs. of fuel per kilowatt hour.

Milwaukee Northern Railway, equipped with:

Two 2000 h.p. twin tandem double acting Allis-Chalmers engines, direct connected to two 1300 kw., 3-phase, 60 cycle alternating current generators.

Two 2000 h.p. down-draft bituminous gas generating plants. Service, 24 hours daily for one engine; the other engine in service during the peak loads, averaging 8 hours per day.

Record of fuel charged to the plant and kilowatt output at the switchboard for the year on a 12 per cent. station load factor shows 1.97 lbs. per kilowatt hour.

Swift & Company, Bartow, Florida, equipped with:

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* From a paper read before Schenectady Section A.I.E.E.

Three 250 h.p., 3 cylinder vertical single acting Rathbun engines direct connected to 60 cycle alternators.

One 750 h.p. bituminous gas generating plant.

Two 30 day commercial tests on West Virginia coal showed an average of 1.26 lbs. of fuel per kilowatt hour on the switchboard at an 80 per cent. load factor.

A full year's run on 40 per cent. load factor showed 1.56 lbs. per kilowatt hour.

If time permitted it would be possible to quote many other plants of various sizes with equally good records, and it is not amiss to emphasize here that, contrary to steam plant practice, the economy of a gas producer engine varies but little with the size. To my knowledge, engines as small as 80 h.p. are habitually producing a brake horsepower-hour on less than 10,000 B.t.u. in gas consumed.

The large gas engine is indebted to the gas producer, more than to any other element, for its economy, wonderful development and rapid adoption.

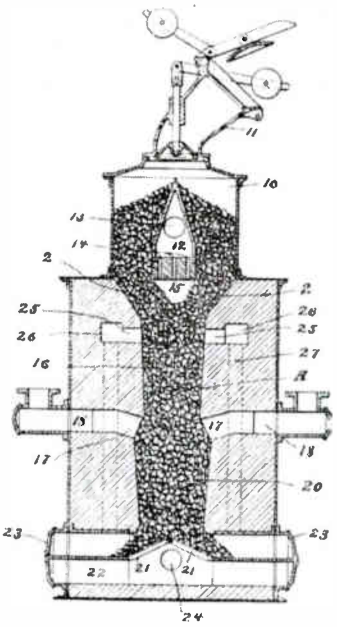
A brief analysis of the several methods of power gas production from solid fuels will, I hope, be interesting.

There are in use to-day two distinct types of gas producers which, by reason of their construction, are adaptable for use with various fuels. The simpler of these is the up-draft anthracite producer. Both types of producers are susceptible to two distinct methods of operation, suction and pressure.

The suction producer, as it is commonly called, is one which, through its scrubber, piping and fittings, is connected directly to the engine inlet pipe. The production of gas is thus automatic and varies with the load on the engine. A brief analysis of the suction producer brings within this catagory any producer which is operated under a vacuum, the gas being drawn from the producer through pipes, scrubber and fittings, and delivered from the exhauster mechanism either through a gas holder or directly to the engine. Such a plant is sometimes erroneously called a pressure producer. The pressure producer proper is one in which the gas is produced by forcing air, steam, or products of combustion through the fuel bed of the producer by pressure. This pressure is sometimes supplied from a fan or blower, but more often from a steam jet blower. Gas made by any of the methods mentioned is not a definite compound, but a mixture of several gases in widely varying proportions. The earliest form of power gas producer was the Dowson producer of 1878.

Dowson Producer

This producer has a cylindrical casing lined with fire brick and fitted at the bottom with fire bars located over a closed ash pit. A fuel hopper, with an internal bell valve, is mounted on the upper part of the producer. Air is forced through the fire by means of a steam jet, the fuel being slowly added from the top until the whole mass is incandescent. The valves of the hopper are then closed and the gas escapes through cooling and scrubbing devices to the gas holder; thence to another scrubber and to the engine.



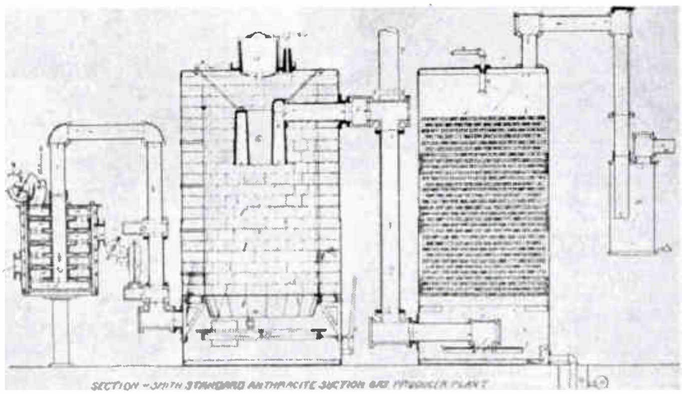
Anthracite Gas Producer

Bernier Producer

The earliest known form of the common suction producer, where the engine suction stroke is communicated directly to the producer, is the Bernier, which was brought out in 1894 by a Frenchman of that name.

This producer is also of cylindrical design lined with fire brick and with the grate at the bottom. Air and steam come from a receptacle at the top of the fuel bed and pass down underneath the fire, through a space between the cylinder carrying the fuels and the outside cylinder. Since the wall of this chamber is hot, the temperature of the air and steam is raised. Entering the grate at the bottom, the steam passes up through the fuel and the gas generated flows out and over into the scrubber, which is of the water sealed type; thence to the engine. Due to its peculiar design, this producer did not prove very satisfactory.

so that a flow of water is had proportional to the amount of this movement. As the suction stroke of the engine is finished, this water carrying device resumes its normal position. The water is converted into superheated steam and the air is pre-heated, the water vapor and air being then carried through into the producer and out as before. This system has another good feature: the gas is taken from the center of the fire instead of from around the sides, thus drawing the air and products of combustion of the fire from the side walls and creating a higher temperature in the center, where it should prevail.



Section of Smith Standard Anthracite Suction Gas Producer Plant

Smith Suction Producer

This producer is built by the Smith Gas Power Co., Lexington, O., and is probably the best known producer on the American market. It differs from the others described in that the steam for the enrichment of the gas is not generated by the heat of the gas producer but by the heat from the exhaust steam of the engine, the air and water passing through pipes which are heated by this steam. The producer also has a water-sealed charging hopper and a swinging grate. The air in entering the producer draws down a movable vane in the superheating chamber, which acts to open a water carrying device

All of the above plants are restricted by their construction to the use of anthracite coal, charcoal or coke.

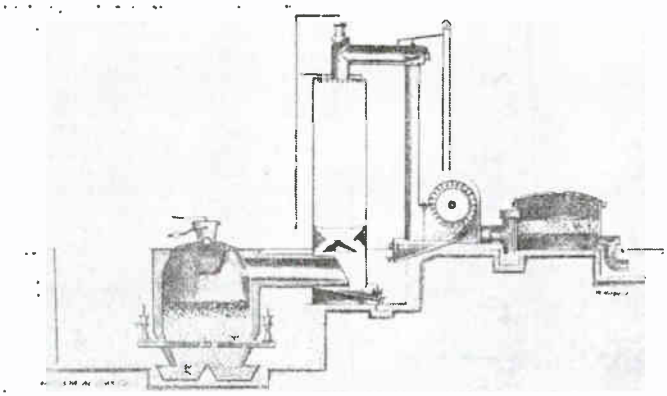
The use of high volatile fuel would result in the formation of tar which, if not removed by means not regularly supplied with these suction producers, would, after formating, almost instantly cause a stoppage of the plant. Tar forming on the inlet valve, stems, igniters and other parts of the engine will cause a stoppage in a very few minutes.

In order to operate on bituminous coal with an up-draft producer, it is absolutely necessary to provide means for the removal of the tar which condenses when the gases are cooled. This is done in a producer built by the R. D. Wood Company by first cooling and washing the gases in a vertical scrubber fitted with coke through which water trickles downward, the gases percolating upward through the interstices of the coke. The cold gas, with part of the tar and dirt removed, is thence taken to a centrifugal extractor which consists of two fans joined together in such a manner that the gases entering the center of the fan are thrown to the periphery by centrifugal force and return against the centrigufal action of an opposed fan, leaving the extractor at the center of the apparatus. The centrifugal force of the two fans is sufficient to keep the tar and other dirts out in a casing beyond the periphery of the fans, whence it is drained and removed. Sometimes even this is not sufficient for a proper cleansing, when sawdust or dry scrubbers are interposed between the extractor and the engine. Tar drip pots are also frequently found in installations of this character, indicating that all of the tar is not removed in at least a single stage centrifugal device.

Other apparatus for the removal of tar consists of relatively wide drums or cylinders fitted with blades arranged to propel the gas in one direction and the water for cleansing in another. The speed of the rotor or drum is sufficient to keep the water and tar against the inner circumference of the surrounding casing. Such apparatus is built by Thieson, Assler and others.

Industrial Producer Plant

Steam and air enter at the bottom under pressure and gas leaves at the top, passing through the scrubber or cooler, where the majority of the tar and dirt is drawn out. Water enters at the top. There is no filling of any kind in the scrubber, dependence being placed entirely upon contact with water for the precipitation of the solids. The gas leaves at the top in a cool condition and enters a centrifugal separator, where the rest of the tar is removed. It then passes to a sawdust scrubber and from there to the engine, the whole system being under pressure.

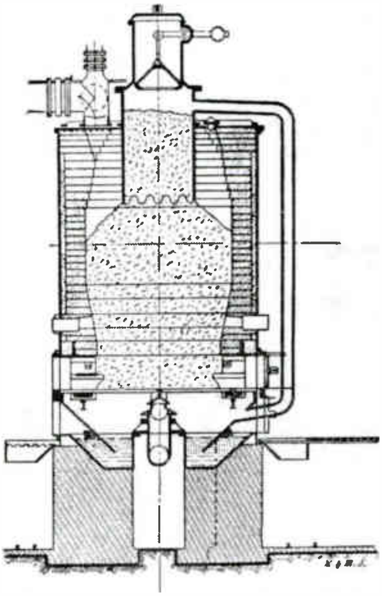


Section of Gas Producer Manufactured by the Industrial Gas Company

Many gas engineers, recognizing the latent danger from tar in the up-draft apparatus, should any of the tar extracting apparatus fail, have devoted themselves to the development of gas-producing apparatus which will eliminate the tar. Descriptions of this class of tar destroying producers follow:

Poetter Gas Producer

The coal is charged from the top as before and is fed down to a lower magazine in the top of the producer. Steam and air are supplied as before and the gas passes upward and out at the top. The hot gases surrounding this fuel reservoir were supposed to serve to drive off the volatile matter, which would then be carried around to the bottom of the producer and burned. Unfortunately this did not work and big engines were crippled on this account.



Section of Poetter Gas Producer

Probably the most successful of the tar destroying producers, and at the same time the most simple, is the down-draft apparatus, where the fuel is charged through an open door at the top and the gas drawn off at the bottom.

Loomis-Pettibone Producer

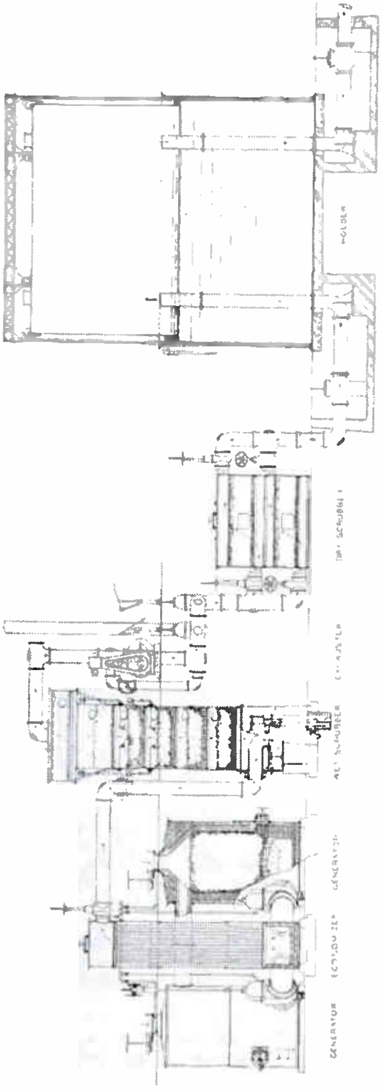
The cut on opposite page shows a section of the Type A Loomis Pettibone gas producer, which is quite extensively used for power generation in this country. Units usually consist of two generators connected together and to an economizer or boiler, where steam is generated. The coal is charged at the top and the gas leaves at the bottom. The grate is of arched fire brick construction. The steam enters the producer through a pipe and is mixed with air and passes down through the fire, completely decomposing the volatiles. The gases, which are heated to about 1200 to 1300° F., leave through fire brick connections at the bottom, thence through the scrubber and gas holder to the engine.

In operating down-draft producers, the smaller portions of the fuel are completely consumed at the top of the fire and, working down by force of gravity and the action of the draft through the fire, serve to plug up the fire, as it were. This congested condition has to be relieved by short reverse runs of compressed air.

These down-draft producers burn anthracite or bituminous coal, wood or charcoal, without producing any tar. It will be observed, however, that partial combustion takes place throughout the whole zone of this producer fire and, contrary to practice in the up-draft type, the greater portion of ash forms at the top and by force of gravity the flow of gas works down through the fire. As a result the fire becomes impregnated with a mass of partially burned coal or coke, ash, clinker and lampblack. If the fire is subjected to a heavy leading, or operated at a high rate of fuel consumption per square foot of grate, the temperatures which ensue will weld this mass of coke, ash and clinker into a very serious conglomeration of hard clinker.

Two methods of cleaning these producers are in vogue, as follows: One partial cleaning, whereby a portion of the fuel bed is withdrawn from the bottom cleaning doors once in every 16 to 24 hours. The remainder of the bed, which by reason of its clinker formation, coke, etc., will bridge across the producer, is then barred down from above and serves as a fixing bed or zone for the next day's run. The laborers sort the larger pieces of coke from the mass of material withdrawn and return it to the producer. A great deal of small or fine coke is lost.

The other method of operating this producer is to run the producer continuously or intermittently until the fuel bed becomes so choked with lampblack, dust, ash and clinker, as to make it impossible to further carry its rated load, when the unit is shut down and the complete mass of material withdrawn from the producer. That this is a trying and difficult occupation cannot be denied. I have in mind a description of the cleaning of such a producer, written by Mr. T. F. Christopher, and I take the liberty of offering several extracts from his description.



Section of Type A Loomis-Pettibone Gas Producer

"There is a type of gas producer in use which is so troublesome to clean out that the job is dreaded by every person who is in any way connected with the operation. The ashes and clinkers to be removed are hot, and as the loose ones are raked out they must be quenched by using a hose. The water thrown on them generates clouds of steam that carry the ashes into the eyes and nose and penetrate every opening in the clothing, at the same time matting the hair and forming crusts around the lips and mouth. No amount of clothing will prevent the limbs and body becoming covered with lampblack, soot and ashes; even the shoes do not protect the feet from being also coated in the same manner. Numerous applications of soap and hot water are necessary to remove this greasy smudge. Every part of the producer room is covered, each projection of stone, brick or wood is a resting place for a pyramid of dust, ready to topple over and again fill the air at the slightest jar or puff of wind. After the loose ashes and small clinkers are removed, there still remains a quantity of larger clinker to be barred loose from the side walls, and still larger and harder ones in the center of the generator which have to be broken up in order to remove them through the doorway. This process of breaking requires long cold chisels and sledge hammers; the clinkers are still hot, and the holding of the chisel must be directed by looking through the doorway, requiring a crouching position, which man cannot maintain long at a time. Consequently, the process is slow as well as laborious and requires a number of men who work in shifts of a few minutes at a time. When this producer is finally emptied and ready to refire, a second one must receive the same attention.

"This type of producer is built with a pair of generators to one boiler and scrubber. After the generators are cleaned, the boiler must have its top removed and flue scrapers run through each flue; then openings near the bottom must be removed and all the soot and ashes, which have been loosened or have accumulated during the week's run, cleaned out. Following this is the meanest job of all—the cleaning of the traps on the gas line between the scrubbers and the gas holder. A new man must be provided at each cleaning to perform this operation. No man will do it a second time; he will quit the job first. It consists in getting down into a pit almost entirely filled with soot or lampblack and shoveling out this material, which is part dry and part wet. The dry portion is very light and floats around, filling the air. It is carried to the lungs with every breath, and it sticks like glue when moistened. The man who performs this job is a walking paint factory for the next week.

"Cleaning out is a regular necessary weekly performance, usually done on Sunday, as it takes all day with eight men and a superintendent. Any good fuel drawn out with the ashes is saved and used in starting new fires. This is a down-draft type of producer using bituminous coal, and when making producer gas it is worked with the top open. Since little steam is admitted with the air, the inclination to clinker is intensified, especially when no attempt is made by the operator to keep the top of the fire bed leveled off, or to stop the draft holes through it. When asked why, one of these operators replied: 'The top is all caked, and if I stop the hole I will have to make another to let the air pass through.'

"I visited a plant of this kind two days in succession, and was then invited to come on Sunday and see a clean-out. Securing some old clothing proper for the occasion, I arrived at the works on time. They started cleaning at 8:30 in the morning, with a half hour rest at noon. The work was completed and new fires started at 5:30 in the afternoon. The best possible wash-up at the plant after the work was finished was made, and this left me about as presentable as a coal passer just out of the stoke hole. The chief operator, who had superintended the work and handled his men well, making every move count, said each weekly operation varied little, if any, from the one witnessed."

Many engineers, for various reasons, are prone to doubt the reliability of gas power. At a recent meeting of the American Society of Mechanical Engineers, this feeling was expressed by several well known engineers.

In the discussion of several papers, a well known engineer severely criticised the many published reports of the economic performances of gas engine power plants, and claimed that the gas power advocates were comparing the best gas power stations with the poorest steam power stations, and cited an instance of a large pumping plant delivering an indicated horse-power on 1.06 pounds of coal. It will be remembered in this connection that the steam pumping station was of large capacity and operating at its most economic load factor. Unfortunately, the gas power advocates had no installation at that time where continuous high load factors obtained, such as was to be expected in the pumping station of the kind mentioned.

With reference to efficiency in gas producer work, I desire to call your attention to the tests recently made by one of our well known engineers on a very economical type of water tube boiler, known as the Rust boiler. In his report the engineer stated that the test results, high as they were, could undoubtedly be duplicated at any time, when the boilers were operated under the same conditions as those existing when the tests were made; that is:

1st: Uniform rate of driving, without the necessity of having to increase or lower the steam pressure or force the fires.

2nd: Boiler absolutely clean inside and out.

3rd. The fire brick furnace free from air leaks.

4th: Automatic stoker.

5th: The draft and the rate of feeding the coal adjusted to each other so as to burn the coal without smoke and without any greater amount of air than is necessary for complete combustion of the fuel.

Can any of us refer to a boiler installation in commercial operation for any length of time under these ideal conditions? I doubt it.

In the gas producer, however, we have a fire brick lined shell with the practical impossibility of any opportunity for leaks of any kind. All the fuel charged into the producer must be delivered in the form of gas to the engines, faulty firing by the operator notwithstanding.

Uneconomical operation is practically impossible but faulty operation or incompetent handling of the apparatus is always attended with a poor grade of gas, which at times causes interruptions of service at the engine. This result, however, is not obtained excepting from criminal negligence on the part of the operator. The labor, therefore, required to operate a modern gas producer is no more intelligent then that required for the stoking of our ordinary steam boilers.

The only element necessary for the emphatic demonstration of the economical claims of gas power advocates is time. It took time, and a great deal of it, to bring our steam equipments to their present state of perfection, and within a very short while, even now, we see large gas power stations operating in service, to which our steam advocates point with pride.

COMMERCIAL ELECTRICAL TESTING

PART IX

By E. F. Collins

INDUCTION MOTORS (Continued)

Torque

Two methods are used for measuring torque on induction motors, one employing a spring balance and the other a special torque indicator.

In the first method a wooden brake lever is clamped around the pulley as shown in Fig. 41. The size and length of lever depends on the size of the motor, the length being chosen to give a maximum reading at one-half or two-thirds the capacity of the spring balance used. Let the point of attachment to the lever be at X; then the length of the lever arm $= XY$. On the frame of the motor a mark should be made at M, and a pointer, P, attached to the lever as shown. The lever arm is then raised until the distance $XT = YS$, and the pointer set so that it is on mark M. If the weight of the lever alone is not sufficient to overcome the friction of the bearings and turn the rotor round till the end of the lever touches the floor, attach a weight at W. Now if the spring balance H is pulled upwards until the pointer P is on mark M, XY will be parallel to TS, and the pull X will make an angle of 90° with the center of the shaft—the position in which all readings must be taken. Open all switches on the dynamometer board to eliminate the residual magnetism of the alternator, raise the lever arm by pulling vertically on the spring balance till the pointer passes the mark M, and at the instant of passing take a reading of the spring balance. Call this reading $W+F$. Let the lever be raised until the pointer is some distance beyond M; then lower the spring balance and let gravity pull the lever toward the floor, reading the balance when the pointer passes the mark. Call this reading $W-F$. To get good readings, the lever arm should be moved rather slowly, but steadily, and with as nearly constant speed as possible, a reading of the balance being taken every time the pointer passes the mark. As a check, three or four readings should be taken as described above.

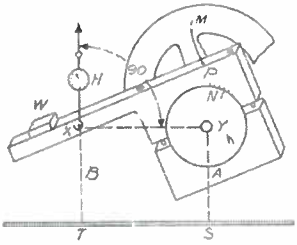


Fig. 41. Measurement of Torque by Means of Spring Balance

Close the line switches and increase the amperes to twice normal and take readings as before; also read volts and amperes. Call the reading obtained as the pointer passes the mark as the lever goes up, $W+F+T$, and that obtained as the lever comes down, $W-F+T$, T representing torque.

Readings should be recorded as below, assuming that they were taken on a 440 volt motor:

Volts, 150; Amps., 40; $W+F$, 9 lbs.; $W-F$, 5 lbs.; $W+F+T$, 19 lbs.; $W-F+T$, 15 lbs.; T, 10 lbs.

To find the torque:

$2W = 14 \ldots w = 7$ lbs.

$2(W+T) = 34$ lbs.

$T = 10$ lbs.

Torque at 1 ft. radius $T \times L$

Where $L =$ length of lever arm

Torque at 1 ft. radius at normal volts

$$= \frac{(\text{normal volts})^2}{(\text{volts read})} \times T \times L$$

On squirrel cage or wound rotors a value of current should be used which will make $W+F+T$ at least twice $W+F$. The maximum and minimum values of $W+F+T$ and of $W-F+T$ should also be taken.

All wound rotors and most squirrel cage rotors will show a torque variation depending on the rotor position.

As a check on the torque readings, the lever should be loosened on the pulley and the pulley rolled forward until the mark on its rim at N is in line with a second mark on the lever arm, thus changing the relative positions of the rotor and stator. Further readings should be taken and this procedure repeated for four or five different points. The torque should be the same for all points on Form K motors.

A special consideration to be observed in making a test for torque is the maintaining of a constant and correct generator speed. The volts read, when amperes are 200 per cent. normal on the first point, should be held constant on all other points, since the torque varies as the square of the volts. The torque also increases as the resistance of the rotor winding increases owing to heating. On large machines the rotor winding sometimes becomes quite hot, so that the temperature of the end rings and bars of the winding should be taken and recorded.

Starting Resistance

The Form L motor has a starting resistance in the rotor which in the smaller sizes is controlled by means of a rod sliding within the shaft and in the larger machines by a lever and ratchet combination. The resistance of the different starting steps must be measured.

The rod should be pulled out to the full extent by means of the knob handle, thus putting all the resistance in circuit. The rod is then divided into five equal parts and from the impedance test the voltage that will give about 125 per cent. normal amperes when the rod is in the running position (resistance all cut out) is found. Apply this voltage, and with the rod in the first position read volts and amperes stator. Similar readings should be taken on each of five different steps marked on the rod. The same procedure holds good for the larger machines, where the resistance is cut out step by step. These readings, with the resistance in circuit, must be taken as quickly as possible, otherwise the resistance becomes unduly heated and may be injured.

Table XVIII shows the form used in calculating stationary torque on induction motors.

Efficiency

Input-output efficiency and power factor tests can be made by either the "string brake" or "pumping back" methods. Neither of these methods are particularly accurate nor are they recommended. In certain cases, however, these tests are made on induction motors, though not on any other type of alternating or direct current motor.

In the "brake method" the size of the brake limits the size of the motor tested. In Fig. 42, *L* is a lever or scale beam suspended at the point *X*. From *T* the small platform *A* is suspended, on which calibrated weights are placed. *P* is a *flat* faced pulley on the shaft of the motor, running in the direction shown by the arrow; *i.e.*, toward the lever *L*. One end of a small rope is attached at *B*, which is wound one or more times around the pulley. The other end is made fast to a spring balance *G*. A strip bearing a mark is located at *K* so that when the point of the lever *L* comes opposite to the mark, the lever is in a horizontal position at an angle of 90 degrees to the force exerted by the pulley.

Since the stress along a rope is transmitted through its center, adjust the brake until the points *M* and *N* are a distance apart equal to the diameter of the pulley plus the diameter of the rope, one-half the diameter of the rope being added to each side of the pulley. This adjustment must be accurately made and care taken to see that nothing moves to throw the brake out of line or proper adjustment. When ready, slip the rope off the pulley but leave it attached at *B* and *G*, then balance the lever until the pointer on the end comes to rest at the mark *K*. This balancing of *L* must be repeated each time the rope is changed.

The motor should be run light for at least one hour before the test proper is commenced, so that friction may become constant. Since speed is one of the important factors in the output of the motor, it should be taken very carefully. The slip should be taken with the slip machine.

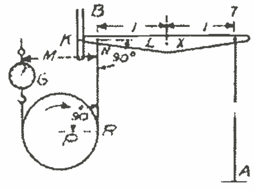


Fig. 42. Diagram of Apparatus Used in Taking Input Output by the String Brake Method

Running light readings should now be taken on the motor, the impressed voltage, as well as the frequency, being held constant. A small weight is next attached to the spring balance to give enough tension on the spring for a reading on the balance of a quarter or half a pound. This "no load" scale reading must be recorded and subtracted from all subsequent readings taken.

A small weight is now placed on *A* and the spring balance *G* pulled up until the pointer on lever *L* reaches *K*; when the motor volts and speed of the generator are normal and all meters are steady, the volts, amperes, watts, weights on *A*, spring balance deflection, and speed given by the tachometer should be read. A reading should also be taken with the slip machine. Continue to add weight to *A* and take readings until the breakdown load of the motor is reached. The readings should be recorded in the following manner:

Volts Amps.	+ Watts	− Watts	WEIGHT TENSION		Speed of Slip Motor
			On *A*	On Balance	

A rope of small diameter gives better results than one of larger diameter, even though it may require more time to make the tests on account of having to renew the rope more frequently. For motors up to 20 h.p., a ¼ in. oiled hemp rope is best, and for motors from 20 h.p. to 50 h.p., a ½ in. rope can be used. The rope will usually last longer if doubled, and two strands used in parallel. The rope should be wrapped around the pulley one and a half times, care being taken to have no strands twisted or crossing each other; all strands should lie closely and evenly together on the face of the pulley. The tension read on the balance *G* will vary with the temperature of the rope and may differ widely with different loads.

The additional weight added to *A* each time should be such as to allow of from fifteen to twenty readings between no-load and breakdown.

When the breakdown point has been reached and complete readings taken and recorded, the diameter of the pulley should be carefully measured.

Weight on *A* − (tension on balance) − ("no load" reading on balance) = actual load in pounds = *P*.

Normal speed − slip = actual speed of motor.

R = radius of pulley in inches + ½ diameter of rope.

S = speed in revolutions per minute.

$$\text{Power factor} = \frac{\text{watts}}{\text{volts and amps.}}$$

$$\text{Then horse-power} = \frac{2\pi R}{P \times 12 \times S \times 33{,}000}.$$

$$\text{Efficiency} = \frac{\text{horse-power output} \times 746}{\text{watts input}}$$

Considering Fig. 43, let *M* be the motor and *L* the load machine, the latter being a direct current machine of about the same capacity as the motor, belted to the motor and separately excited from a suitable source.

To make the efficiency test, connect *M* so that the total input can be obtained. The necessary connections are not given, as they vary widely, depending on whether *M* is a one, two or three-phase machine. Separately excite the field of *L* and connect an ammeter and a variable resistance in circuit. Connect the armature of *L* to a

TABLE XVIII

STATIONARY TORQUE ON A 15 H.P., 220 V., 6-POLE, 60 CYCLE, 2-PHASE INDUCTION MOTOR

Lever Arm	Controller Pos.	Volts	Amps	W + F	W − F	W + F − C	W − F + 1	W	W − F	T	[illegible]
2 ft.	1	220	21 41	16.25	11.25	33	33	15.25	33	17.75	35.5
	2	220	36 39	17.25	14.25	50.75	48.75	15.75	49.75	34	68
2.292 ft.	2	220	38-37	17.25	16.25	47.75	47.75	16.75	47.75	31	71
	3	220	57 54	17.25	16.25	54.75	53.75	16.75	54.25	37.5	86
	4	220	96 41	17.25	17.25	67	66	17.25	66.5	49.25	113
	4	220	98 45	17.25	17.25	68	66	17.25	67	49.75	114
	6	209	121 82	16.25	16.25	78	78	16.25	78	61.75	136
	7	187	105-97	17.25	16.25	61.75	59.75	16.75	60.75	44	139
	8	175	173 162	16.25	15.25	51.75	50.75	15.75	51.25	35.5	128.7

Lever Arm. = 2 ft. and 2.292 ft.
Normal running torque at 1 ft. radius = 63.6 lbs.

water-box or to a motor, the load of which can be varied. An ammeter should be placed in the circuit and a voltmeter across the brush terminals. If the test involves a considerable range of speeds, run M over that range and hold the field current of L constant, its value being such that the speeds or loads required for M can be obtained.

Having made the necessary connections, etc., keep the field current of L constant at its predetermined value. Vary the load on L by changing the water resistance or the load on the motor to which it is connected to suit the testing conditions required on M. The efficiency of M may be required for a series of speeds or of loads. Read the input and speed of M and the volts and amperes of L. Vary its speed from slightly below to slightly above the speeds used before when running as a motor and take a number of readings at different speeds, reading volts and amperes input and speed; L being separately excited with the same value of current that was used in the two previous cases. The necessary readings are now complete for calculating the efficiency.

Case A

Let Wm be the total input of M.

Let Wl be the product of volts and amperes read for L.

Let Fm be M's friction, windage, etc.

Let Fl be L's friction, windage, etc.

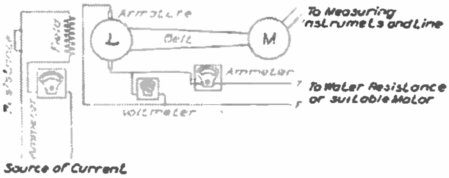


Fig. 43. Connections for Measuring Input Output by Pumping Back

The "counter torque" must now be obtained to complete the calculations. To obtain this, disconnect M, connect L to a source of current which can be varied so as to give L different speeds, keeping L separately excited. If the "pumping back" method for loading L has been used, the connection will probably not require any change. Run L as a motor driving M, keeping the field current of L constant at the same value that it had when L was used as a generator.

Vary the speed of L so that the speed of M can be varied slightly from below its previous minimum speed to slightly above its maximum speed. Take a number of readings at varying speeds, reading volts and amperes input of L and speeds of L and M. If the electrical efficiency alone is desired (Case A), sufficient readings have been taken. If the commercial efficiency is desired (Case B), take off the belt from L and run it light as a motor.

Divide the belt friction equally between L and M, including this in Fm and Fl.

Let R be the hot resistance of L's armature, which must be measured.

Let C be the current in L's armature.

Then electrical efficiency $= \dfrac{Wl + C^2R + CT}{Wm}$

where CT is the mechanical losses in L and M and the belt loss.

For Case B

Efficiency $= \dfrac{Wl+C^2R+CT}{Wm}$ where CT is the mechanical losses of L, including belt loss.

In running the counter torque curves, the field of L must be held constant throughout and readings must not be taken when accelerating.

(To be continued)

DUCTILE TUNGSTEN AND MOLYBDENUM*

By Colin G. Fink, Ph.D.

Tungsten has heretofore been known chiefly as a steel-hardening metal. In recent years, however, it has become an important material for filaments of incandescent lamps, and is today the most efficient metal for this purpose, owing to its high melting point (3000° C.), which is higher than that of any other metal, and its low vapor tension.

It is well known that tungsten is described in all of the textbooks as a brittle gray metal, and that numerous attempts have been made to reduce it to ductile form, as is evidenced by publications emanating from various research laboratories. Roscoe and Schorlemmer, in the latest edition of their "Treatise on Chemistry" state that "the purest forms of tungsten at present obtainable are hard and brittle and are not ductile, either at ordinary temperatures or when heated."

The metal has ordinarily been obtainable in commerce in the form of a dark gray powder, usually made by the reduction of the yellow oxide by hydrogen or by carbon. This powder, when bought on the open market, is generally impure, and is purified by various well known methods, particularly if the metal is to be used for filaments of incandescent lamps. These filaments have been made on a large scale and are in common use in this country and abroad. Even in ordinary commercial lamps, the filaments are of a degree of purity so high that no impurities can be discovered by the most searching methods of chemical analysis known. Not only is this true, but these filaments, during the course of commercial production, are exposed to temperatures high enough to drive out by mere vaporization almost any impurity.

Nevertheless, these filaments show no traces whatever of ductility, or even pliability, but on the contrary, though strong enough for mounting in commercial lamps, they are exceedingly brittle and incapable of taking a permanent set. Attempts have hitherto been made—but always without success—to produce ductile tungsten by various purification processes, varying the ore from which the tungsten is obtained by trying first wolframite (an iron-manganese tungstate) and then scheelite (the calcium tungstate). Whichever ore is used, it is customary to produce from it the yellow oxide, and a high degree of purity has been sought by repeated precipitations. Various methods of reduction have been tried; among other reducing agents, hydrogen, carbon, aluminum, zinc and magnesium have been used. Reduction has also been effected by electrolytic methods. Since tungsten metal produced in this way has been so pure that no impurities could be detected by ordinary chemical or physical means, and has yet retained its characteristic hardness and brittleness, it has generally been concluded that the metal is entirely lacking in that physical property which is ordinarily termed ductility.

Announcement has recently been made, however, of the production of tungsten in a form in which it is ductile. This ductile tungsten would seem to be a new substance, from the point of view of the physical chemist,

TABLE I—TENSILE STRENGTH

Tungsten Wire

Diam. in mm	5.0 0.125	2.8 0.070	1.5 0.038	1.2 0.030
Lbs. per sq. in.	460,000 to 490,000	480,000 to 530,000	550,000 to 600,000	580,000 to 610,000
Kg. per sq. mm.	322 to 343	336 to 371	385 to 420	406 to 427

Molybdenum Wire

Lbs. per sq. in.	200,000 to 260,000	230,000 to 270,000	270,000 to 310,000	....
Kg. per sq. mm.	140 to 182	161 to 189	180 to 217	....

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* Paper presented before American Electro Chemical Society, May 5, 1910.

and it has seemed to me that this society would be interested in learning something of the properties of this product, since only those of us who have been connected with the Research Laboratory of the General Electric Company have as yet had an opportunity to study it.

Ductile tungsten is a bright, tough, steel-colored metal, which can be drawn into the finest wire, much below one thousandth of an inch. The tensile strength of the wire increases as the drawing proceeds; or, in other words, the more the metal is mechanically worked, the tougher and stronger it gets. In the following table a few figures on the strength of tungsten wires are given. They are the average obtained from a large number of measurements.

A piece of hard drawn piano wire, tested with the same apparatus, registered, on the average, 507,000 lbs. (35 kg. per sq. mm.), the diameter of the wire being 3 thousandths of an inch (0.075 mm.). According to Schnabel, aluminum shows a similar behavior as regards the effect of drawing: Cast aluminum gives but 17,000 lbs. per square inch (11.9 kg. per sq. mm.), whereas the drawn metal has a tensile strength of 36,000 to 39,000 lbs. (25.2 to 27.3 kg. per sq. mm.)

The density or specific gravity values of ductile tungsten likewise increase with the amount of working. The values for ductile molybdenum were also determined at our laboratory.

TABLE II—SPECIFIC GRAVITY

DIAMETER Inches	DIAMETER mm.	Tungsten	Molybdenum
Before Drawing			
		18.81	10.02
After Drawing			
0.150	3.75.	19.30 to 19.30	10.04
0.010	0.25.	19.58 to 19.64	10.29
0.0015	0.038.	19.86 to 20.19	10.32

Martin (1907) found the density of melted tungsten, analyzing 98.96 per cent. pure, to be 16.28; Moissan (1896) and Weiss (1910) give the values of 18.70 and 18.72 for the brittle metal. As is seen from the table, the density increases very appreciably with the amount of mechanical working applied. This same phenomenon is well known in the case of copper, zinc and other metals. The density of cast copper according to Marchand and Scheerer is 8.92, and that of rolled and hammered copper 9.95. Distilled zinc gives 6.92 and wrought zinc 7.25.

The electrical resistance and the temperature coefficient of the two metals are given in Table 3. We used the Wheatstone bridge method. The resistance was measured at room temperature and at 170°, employing two oil thermostats.

TABLE III

		Resistivity (25°) in microhms per cu. cm.	Temp. Coeff. per degree between 0° and 170° C.
Tungsten	*d.*	6.2	0.0051
	a.	5.0	
Molybdenum	*d.*	5.6	0.0050
	a.	4.8	

The values marked *d* are for hard drawn wire; those marked *a* were obtained after annealing. This resistivity value for tungsten is a good deal lower than that given by Gin (Trans. Am. Electrochem. Soc. XIII, 483). The coefficient for copper (0° to 160°) is 0.00445 (Reichardt); the registry values for copper are 1.62 for the hard drawn and 1.58 for the annealed wire.

The hardness of both tungsten and molybdenum depends very much upon the amount of mechanical working to which the metals have been subjected, and also upon the presence of impurities. Whereas the hard varieties scratch glass, the soft varieties are easily cut with a file.

The thermal coefficients of the two metals were determined on wire 5 thousandths of an inch in diameter. A reading of one degree on the scale was equivalent to an elongation of the wire of 0.000345 inches. The values obtained are $336 \times 10_r^{-8}$ for tungsten and $360 \times 10_r^{-8}$ for molybdenum, the temperature range being 20° – 100°. The platinum value for the same range is $884 \times 10_r^{-8}$ (Dulong and Pitit).

Chemically, the two ductile metals behave similarly in many respects. The drawn wire retains its lustre almost indefinitely. Both metals are readily attacked by fused oxidizing salts, such as $NaNO_3$, $KHSO_4$ and Na_2O_2. Acids (HCl, HNO_3, H_2SO_4) attack tungsten very slowly, but molybdenum rather readily. I have heated fine drawn tungsten wire in a mixture of chromic and sulphuric acids for sixteen hours but could detect only a very small loss in weight.

Original weight: 16.7330 grams; after 16 hrs., 16.7329 grams.

Original weight: 1.3638 grams; after 14 hrs., 1.3635 grams.

Apparently the metal becomes passive just like iron.

ELECTRIC CURRENT IN RAIN AND SNOW STORMS

By J. B. Taylor

The Meteorological Office of the government of India has recently been making a systematic record of the amount of electricity brought down by rain. These records show that for 70 per cent. of the rain storms, the particles of water are charged positively, and during some exceptional storms, measurements of the charge brought along with each cubic centimeter of rain water, in connection with the rate of rainfall, gives a current of about 300×10^{-18} amperes per square centimeter of the earth's surface.

Expressed in these units, we do not have any tangible idea of the current strength in the rain, but by changing the unit of area from the square centimeter to the square mile, the current in the latter area is found to be approximately 10 amperes.

For those who wish more data on these Indian records, reference may be made to a paper by G. C. Simpson, in the Royal Society Proceedings, May 6, 1909.

An abstract of this paper recalled to the writer some tests and measurements made ten or eleven years ago on telephone lines during snow storms. These tests have already been referred to in the discussion of an A.I.E.E. paper *, the point of the discussion being to show that, under some conditions, each individual snow flake carries a charge and that a telephone line some miles in length will be struck by a sufficient number of these flakes to give, if the line be connected to earth, a practically steady current of such magnitude as to be easily read on commercial measuring instruments.

A recollection of this test in connection with the figures on rain drop charges in India, has led to some additional calculation, based on the data of the snow storm test.

On one occasion, with a metallic circuit telephone line approximately 60 miles long, a Weston voltmeter between telephone wires and ground indicated a steady current of approximately 0.003 of an ampere. If we take the diameter of each wire as $\frac{1}{10}$ of an inch, the 60 miles of line (2 wires) will have a total projected area of $2 \times 60 \times \frac{1}{10} \times \frac{1}{5280} \times \frac{1}{12}$ square miles, which equals approximately $\frac{1}{5280}$ of a square mile. Since 0.003 of an ampere is carried by snow flakes striking this area, we may say, roughly, that under the average conditions at time of test, a current of $\frac{3}{1000} + \frac{1}{5280}$, or 16 amperes was flowing from clouds to each square mile of earth, through the medium of the snow flakes. It is interesting to note that this figure is very nearly the same as that deduced from the electrostatic measurement of charge from the rain test in India.

The Royal Society paper referred to gives further interesting data on the electrification of water particles in a stream of air, and outlines a theory for the formation of thunder clouds.

Since positive charges sufficient to represent a current of 10 or 15 amperes per square mile can not come to earth without leaving an equivalent negative charge in the clouds, it should be apparent that from these figures we have some basis for estimating the quantity of electricity involved in a lightning flash, provided we have data on the number of flashes in a given area in a given time, as well as data on the amount of charge brought to earth by the rain.

While lightning discharges and thunder are not entirely unknown during snow storms, they are unusual; and it is interesting to speculate as to what becomes of the negative charge during a snow storm which is bringing sufficient charge to earth to represent a current of 15 amperes per square mile.

It does not appear that we have yet sufficient data to elaborate any theory, and before such information can be of much value in analyzing thunder storm conditions, it would seem necessary to have simultaneous measurements made at many points over an extensive area, of the polarity and the amount of charge in rain drops or snow flakes.

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*Transactions of the A.I.E.E. Vol. XXIV, Page 990.

HYPERBOLIC FUNCTIONS AND THEIR APPLICATION TO TRANSMISSION LINE PROBLEMS

Part IV

By W. E. Miller

Telephone Lines

As already mentioned, the hyperbolic equations can be applied to accurately determine the variation of volts, amperes and power factor along telephone lines. If the length of the line is considerable, the hyperbolic functions must be separately determined for each point, the functions given in the Review Supplement not covering the range required. The reduction formulæ (see page 221, May Review) can be used to advantage in such cases. In these problems, it is usual to consider that the very complex speech wave can be approximately represented by a wave having the average frequency, this being about 800 cycles per second. Where, however, an accurate representation of the phase and amplitude changes of the wave are required at each point of the line, the method outlined in the editorial of the May Review must be followed; that is, the equations must be applied to each harmonic separately.

In telephone lines, the electrical conditions at the sending or receiving end are only those that generally require determining, and the conditions along the line are not of great importance from a practical point of view. For air lines longer than 700 miles, the hyperbolic equations can then be considerably simplified, since in such lines the wave reflected at the receiving end is negligible at the sending end. Equations (23) and (24), page 222, May Review, can then be reduced as follows, by substituting the exponential values of the hyperbolic functions.

Thus

$$e_s = E_r \cosh mx + I_r m_1 \sinh mx = \frac{E_r}{2}\left(\epsilon^{mx} + \epsilon^{-mx}\right) + \frac{I_r}{2} m_1 \left(\epsilon^{mx} - \epsilon^{-mx}\right)$$

Now x, the line length in miles, is measured from the receiving end; hence ϵ^{mx} increases from the receiving to the sending end, whereas, ϵ^{-mx} decreases between the same points; that is to say, ϵ^{mx} can be regarded as measuring the decrease of amplitude, and the phase change of the wave transmitted from the sending end and ϵ^{-mx} the decrease of the amplitude, and the phase change of the wave reflected from the receiving end, the latter becoming vanishingly small at the sending end in long lines and, therefore, negligible. Thus, the volts at the sending end equal $\frac{\epsilon^{mx}}{2}\left(E_r + I_r m_1\right)$. Similarly, the current at the sending end $= \frac{\epsilon^{mx}}{2}\left(I_r + \frac{E_r}{m_1}\right)$

If $m = a + jb$ then $\epsilon^{mx} = \epsilon^{x(a+jb)} = \epsilon^{ax} \times \epsilon^{jbx}$

Since $\epsilon^{jbx} = \cos bx + j \sin bx$ (see formulæ (10) and (11), page 179, April Review), the equations can be written

$$e_s = \frac{\epsilon^{ax}}{2}\left(E_r + I_r m_1\right)\left(\cos bx + j \sin bx\right) \qquad (35)$$

and

$$i_s = \frac{\epsilon^{ax}}{2}\left(I_r + \frac{E_r}{m_1}\right)\left(\cos bx + j \sin bx\right) \qquad (36)$$

when x = length of the line in miles. These equations are accurate only at or near the transmitting end.

Thus ϵ^{ax} measures the rate of decay of the volts or current from the sending end along the line, a being called the attenuation constant per mile for the line at the given frequency.

The trigonometrical function terms measure the rate of phase twist; that is, b is inversely proportional to the wave length, or $\frac{2\pi}{b}$ = wave length where

$$b = \sqrt{\frac{pC}{2}\left(pL + \sqrt{r^2 + p^2L^2}\right)} \qquad (37)$$

The value of the attenuation constant a is

$$a = \frac{r\sqrt{pC}}{\sqrt{2\left(pL + \sqrt{r^2 + p^2L^2}\right)}} = \sqrt{\frac{pC\left(\sqrt{r^2 + p^2L^2} - pL\right)}{\sqrt{2}}} \qquad (38)$$

These values follow immediately from the value of m given in formula 27, page 222, May Review; a being the real part of m and b the j term. They can, however, be more readily calculated by equating the real terms of the value of the expression m^2 to the real terms of the value of the expression $(a+jb)^2$, and by equating the lengths of these vectors together. If this is done, b^2 or a^2 can be at once eliminated and the values of a or b found.

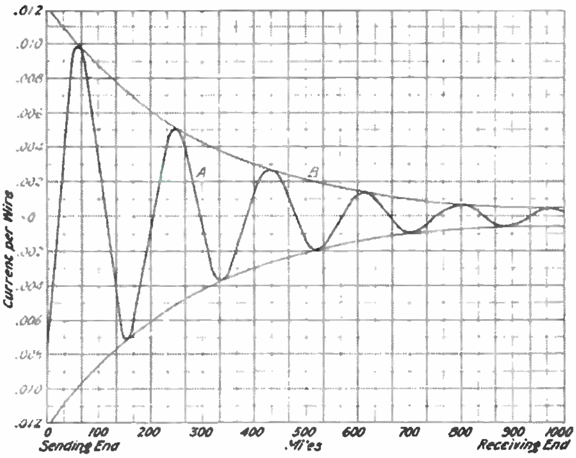

Fig. 17. Curve B Gives Maximum Values of Amperes Along a 1000 Mile Telephone Line Using Two No. 6 B.& S. Copper Wires 12 Inches Apart. Frequency 1000 Cycles. Curve A Gives Instantaneous Values. Receiving End, .20 Volts Between Wires, .50 Milli-Amperes at .50 Power Factor Lagging

From calculations from equations (23) and (24), page 222, May REVIEW, Figs. 16 and 17 have been drawn to show how the volts and current vary along a telephone line consisting of two No. 6 B.&S. copper wires twelve inches apart, the length of line being 1000 miles and the frequency 1000 cycles per second. The instantaneous, as well as the maximum, values of the current and voltage are plotted to show the shift of phase along the line at the epoch chosen at the receiving end. The telephone receiving apparatus is assumed to require .2 volts and ½ milliampere at a power factor .50 lagging. The epoch chosen at the receiving end is that at which the volts are maximum, the current being, at this power factor, half its maximum value at that moment. The attenuation constant of this line for 1000 cycles per second is .0035 per mile and the wave length 183 miles. Harmonics of lower frequency will have smaller attenuation constants and those of higher frequency than 1000 greater attenuation constants, as will be seen from equation (38). The number of complete phase reversals along this line is $\frac{1000}{183}$; that is, over five complete reversals. As the power factor along the line is approximately unity (see Fig. 18), the velocity of the propagation of power along the line can be taken as $183 \times 1000 = 183{,}000$ miles per second without great error, and therefore the time required for transmission is about $\frac{1}{200}$th of a second.

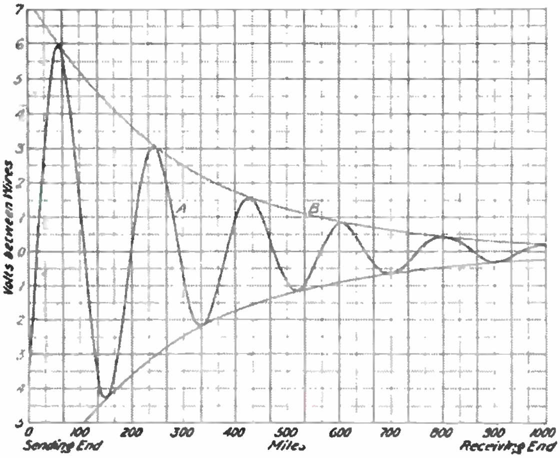

Fig. 16. Curve B Gives Maximum Values of Volts Along a 1000 Mile Telephone Line Using Two No. 6 B.& S. Copper Wires 12 Inches Apart. Frequency 1000 Cycles. Curve A Gives Instantaneous Values. Receiving End, .20 Volts Between Wires, .50 Milli-Amperes at .50 Power Factor Lagging

Loaded Telephone Lines

As already mentioned, the electric wave transmitted along telephone lines is extremely complex, containing both even and odd harmonics, which are usually considered to range from about 200 up to 2400 cycles per second or more. Under ordinary conditions, the higher the frequency of the harmonic, the more is its amplitude attenuated; thus the quality of the sound received may be entirely different to that transmitted and, in long aerial lines or through shorter submarine cables which necessarily possess high inductive capacity, the received wave may be so different from that transmitted as to prevent clear conversation between the points. Some of the higher harmonics may be entirely wiped out in their passage along the line. This is usually called wave distortion. Besides the unequal decrease of each harmonic's amplitude along the line, the speed at which each harmonic is transmitted is different, so that the received wave is built up of harmonics with entirely different phase relations from those that obtain in the transmitted wave.

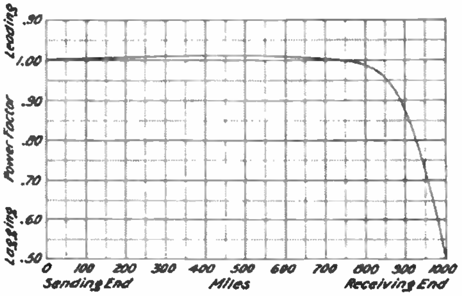

Fig. 18. Variation of Power Factor Along 1000 Mile Telephone Line, Using Two No. 6 B.& S. Copper Wires 12 Inches Apart. Frequency 1000 Cycles. Receiving End, .20 Volts Between Wires, .50 Milli-Amperes at .50 Power Factor Lagging

Phase relations alone, however, do not affect hearing, since the ear can pick out and respond to each harmonic separately, the brain synthesizing the harmonics into the same sound, no matter what the phase relations of the harmonics, provided the harmonics retain the same relative amplitudes. If this were not the case, the positions of the various instruments in an orchestra, relative to the audience, would determine the sound produced at different points. In fact, music in its present form would be impossible.

To overcome the difficulty of the unequal attenuation of each harmonic, various schemes have been proposed. To reduce the attenuation constant, a common practice is to load telephone cables by inserting induction coils spaced at equal distances along the line. This method was introduced by Pupin and gives good results in practice. The coils should not be placed at greater intervals than ⅛ of the wave length of the normal frequency harmonic, otherwise reflection will occur at each coil, and calculations from equations formed on the assumption of uniformly distributed inductance will be vitiated.

An interesting example of this method of loading is found in the recently completed submarine cable which will be laid under the English Channel between Abbott's Cliff and Cape Gris Nez, a distance of about 24 miles. Iron cored induction coils are inserted in the cable every nautical mile. By their means, the attenuation constant at 750 cycles per second has been reduced from .045 to .014 per mile. This cable will be connected by means of an air line to Paris from the French side and to London from the English. It is contemplated extending the line to Scotland.

The cable was made by Siemens Brothers and contains duplicate telephone lines, having a resistance of 12½ ohms per loop mile and a capacity of .12 microfarads between wires. Thus the capacity is about 12 times the usual capacity of air lines. The induction coils each have a resistance of 6 ohms, with a self induction of .1 henry; *viz.*, about 30 times the self induction between wires per mile of air telephone lines. The diameter of the cable over the induction coils is 4½ inches, and this increased diameter extends for about 3½ ft.

The comparison of the attenuation constants and wave propagation velocities in this loaded cable, with those that would occur in a similar but unloaded cable, for two different frequencies, clearly brings out the advantage of loading. The following calculations were made on the assumption that the self induction due to the induction coils is distributed uniformly along the cable, and that therefore formulæ (37) and (38) apply.

If the cable is loaded and has the circuit constants already given, the attenuation constant per mile at 750 cycles per second equals .01, nearly, which is somewhat lower than the value .014 experimentally determined, as would be expected. The wave length is 12 miles, which gives a wave propagation velocity of 9000 miles per second, or only 1/20 that of light. If the frequency is doubled; that is, if a harmonic with a frequency of 1500 cycles per second is taken, the attenuation constant per mile and velocity of propagation are practically the same as in the previous case. Thus the loading has about the correct value to obtain equal attenuations and velocities over a wide range of harmonics and the quality of the sound at the end of the cable will be practically the same as at the sending end.

Assuming that two No. 10 B.&S. copper wires are used somewhat less than ½ inch apart, which would make the cable capacity and resistance approximately correspond with the values given for these constants, the self induction of the unloaded cable will be about .30 *milli*henrys per mile between wires, as against .10 henrys when the induction coils are included. On this basis, the unloaded cable has an attenuation constant of .056 per mile at 750 cycles and .075 per mile at 1500 cycles; that is, the higher harmonic is damped out more quickly than that of lower frequency. These values are more than five and seven times the corresponding values calculated for the loaded cable. At 750 cycles, the velocity of the wave is 74,000 miles per second, and 100,000 miles per second at 1500 cycles, the latter velocity being 35 per cent. greater than the former.

Thus not only will the various harmonics be unequally attenuated in the unloaded cable, but also the phase relations will appreciably differ at the receiving end from those at the transmitting end, even in the case of a 24 mile cable.

Telephone Lines with Distributed Leakage

If distributed leakage is artificially allowed along the line, it can be shown theoretically that the same attenuation constant can be obtained for all harmonics and that, therefore, the quality of the transmitted wave is unchanged at the receiving end, though its amplitude has been diminished. If the dielectric leakage current per mile is proportional to the voltage at any point, the following proof is applicable to the problem.

$m^2 = (g + jpC)(r + jpL)$, (see page 222, May REVIEW).

If $m = a + jb$, then $a^2 + b^2 = \sqrt{(r^2 + p^2L^2)(g^2 + p^2C^2)}$

and $a^2 - b^2 + 2jab = rg - p^2LC + j(pLg + pCr)$

Then, by equating the real parts of the second equation together and adding it to the first, the values of a^2 and b^2 are immediately obtained, which can be written as follows:

$$2a^2 = \sqrt{(rg + p^2LC)^2 + (rpC - pLg)^2} + rg - p^2LC \quad (39)$$

and

$$2b^2 = \sqrt{(rg + p^2LC)^2 + (rpC - pLg)^2} - rg + p^2LC \quad (40)$$

If, therefore, $rC = Lg$ then $a^2 = rg$ and $b^2 = p^2LC$.

That is to say, if the product of resistance and capacity is equal to the product of the self induction and dielectric conductance per mile, then the attenuation constant a per mile is equal to the square root of the product of the resistance r and the dielectric conductance g per mile, and is independent of the frequency and, therefore, will be the same for every harmonic. The wave length $\frac{2\pi}{b}$ will also vary inversely as the frequency. Hence, the velocity of propagation of each harmonic will be the same, and all harmonics will arrive at the receiving end in the same phase relations as at the transmitting end. In order to obtain this result, the self induction per mile must be artificially increased and the insulation resistance of the cable must also be decreased per mile considerably below normal. Hence, the leakage current per mile must be high, though it must not be increased too much, otherwise the attenuation constant will be too great. This method has theoretical interest, but as it is extremely difficult of application, it has not been used in commercial work so far as the author is aware.

Exponential Values of Accurate Transmission and Telephone Line Equations

Equations 23, 24, 25, 26, page 222, May REVIEW, can be written as follows by substituting the exponential and trigonometrical values of the hyperbolics. In this form, the direct and reflected waves are separated and the physical meaning of the equations is clearer than when written in the hyperbolic form, although the equations are not so well adapted for calculations. Steinmetz uses the exponential form in his "Transient Electric Phenomena."

If $m = a + jb$; that is, a is the real term of the constant m given in the REVIEW supplement and b is the j term. As already stated, a is called the attenuation constant per mile and b is the inverse of the wave length; that is, wave length $= \frac{2\pi}{b}$. The constants m_1 and $\frac{1}{m_1}$ per mile have the same values as given in the

Review Supplement for the frequencies 25 and 60 cycles, and given circuit constants.

When the conditions are determined at the receiving end and x is the distance in miles measured from this end, then

$$e=\frac{\epsilon^{ax}}{2}\left(E_r+I_r m_1\right)\left(\cos bx+j\sin bx\right)$$
$$+\frac{\epsilon^{-ax}}{2}\left(E_r-I_r m_1\right)\left(\cos bx-j\sin bx\right)\quad(41)$$
$$i=\frac{\epsilon^{ax}}{2}\left(I_r+\frac{E_r}{m_1}\right)\left(\cos bx+j\sin bx\right)$$
$$+\frac{\epsilon^{-ax}}{2}\left(I_r-\frac{E_r}{m_1}\right)\left(\cos bx-j\sin bx\right)\quad(42)$$

When the conditions are determined at the generator or sending end, and the distance x in miles is measured from this end, then

$$e=\frac{\epsilon^{ax}}{2}\left(E_s-I_s m_1\right)\left(\cos bx+j\sin bx\right)$$
$$+\frac{\epsilon^{-ax}}{2}\left(E_s+I_s m_1\right)\left(\cos bx-j\sin bx\right)\quad(43)$$
$$i=\frac{\epsilon^{ax}}{2}\left(I_s-\frac{E_s}{m_1}\right)\left(\cos bx+j\sin bx\right)$$
$$+\frac{\epsilon^{-ax}}{2}\left(I_s+\frac{E_s}{m_1}\right)\left(\cos bx-j\sin bx\right)\quad(44)$$

In the case of telephone lines or cables, the constants a and b can be calculated for any frequency or line constants from equations (37) and (38) respectively. The constants m_1 and $\frac{1}{m_1}$ can then be calculated from formulæ (28) and (29), page 222, May Review. The values so obtained must be substituted in the equations for each harmonic and the variation of that harmonic along the line can then be calculated. The sum of the instantaneous values of all harmonics at any point of the line gives the instantaneous value of the complex wave at that point.

It must be remembered in the case of telephone lines that if the volts between wires are substituted in the equations, L and C must be given in henrys and farads per mile between wires, and r in ohms per loop mile. The value of p is $2\pi f$ where f is the frequency.

Sign Conventions As Affecting Equations, Constants and Hyperbolic Functions

In all that precedes, a contraclockwise rotation of the current or voltage vector represents a current or voltage leading the standard phase; a clockwise rotation represents a lagging current or voltage. That is to say, a leading current is written $i=i_1+ji_2$, and a lagging current $i=i_1-ji_2$, voltages being written in a similar manner. With this notation impedance is written $r+jpL$ and admittance $g+jpC$. This notation has been used in the Supplement as well as in these articles.

If the opposite notation is used; that is to say, if a minus sign is placed in front of the j term for a leading voltage or current, and a positive sign for a lagging voltage or current, then impedance is written $r-jpL$, and admittance $g-jpC$, and the following changes must be made. The constant m must be written $a-jb$ instead of $a+jb$, and, therefore, the values of $\cosh mx$ and $\sinh mx$ must have the negative sign prefixed before the j term instead of the positive sign. The constant m_1 must be written with the positive sign before its j term, and the constant $\frac{1}{m_1}$ with the negative sign before its j term. In fact, the signs in front of the j terms for currents, voltages, constants or values of the hyperbolic functions must be changed from plus to minus or vice versa in order to make them correspond to the change of notation. The numerical values are, of course, unaltered, and no changes must be made in the signs prefixed before the real terms of any quantity.

In the case of the exponential forms of the hyperbolic equations, Nos. 41, 42, 43 and 44, the complex trigonometrical expressions must be interchanged in each equation; that is to say, the trigonometrical complex multiplier of ϵ^{ax} must have a negative sign placed before its j term and the multiplier of ϵ^{-ax} must have a plus sign placed before its j term. The constants m_1 and $\frac{1}{m_1}$ must also be changed as noted above.

Also, in the approximate equations for short lines, Nos. 5, 6, 7 and 8, Review Supplement (Nos. 30, 31, 32 and 33, May Review, page 223), the negative sign must be written before the j terms in each equation instead of the positive sign. The constants m_1 and $\frac{1}{m_1}$ must also be changed as noted above.

DETERMINATION OF RESISTANCE STEPS FOR THE ACCELERATION OF SERIES MOTORS

BY E. R. CARICHOFF, M.A., AND HAROLD PENDER, PH.D.

SUMMARY

The problem to be solved is the following:

Given

Speed-current curve of motor corresponding to line voltage V.

The current I_1 at which the controller is to be advanced.

The number of steps (n) in the starting resistance.

To find the proper values of the resistances R_n, R_{n-1} ----- R_3, R_2, R_1, such that the current I_2 taken by the motor at the instant of advance of controller from one step to the next shall be the same for each point of the controller.

In addition to the above symbols let

S_1 = speed from speed current curve corresponding to I_1.

S = speed from speed current curve corresponding to a greater current I.

$$A_1 = \frac{V - I_1 r}{S_1 I_1}$$

$$A = \frac{V - Ir}{SI}$$

$$D = \frac{A_1}{A}$$

Then plot the curve

$$Y = A_1(S_1 - S)(1 + D + D^2 + \text{-----} D^n)$$

against the current I as abscissa.

Case I. A single motor connected through the controller to the line.

Let I_2 be the value of I on the y curve which corresponds to $y = \frac{V - I_1 r}{I_1}$, and S_2 the speed from the speed current curve corresponding to $I = I_2$, and A_2 the corresponding value of A. Put $D_2 = \frac{A_1}{A_2}$; then the proper values for the resistance steps are:

$$\left.\begin{aligned} R_1 &= A_1(S_1 - S_2) \\ R_2 &= R_1(1 + D_2) \\ R_3 &= R_1(1 + D_2 + D_2^2) \\ &\cdot \\ &\cdot \\ &\cdot \\ &\cdot \\ R_n &= R_1(1 + D_2 + D_2^2 + \text{-----} D_2^{n-1}) \end{aligned}\right\} \quad (a)$$

Case II. To find the proper values of the resistance steps for each of two motors in parallel which are changed over from full series at the instant when the current drops to the given value I_1.

Use the same y curve as in Case I, but find the current I_2 corresponding to $\frac{V}{2I_1}$, and let S_2 be the speed from the speed current curve corresponding to this value of I_2, and A_2 the corresponding value of A; putting $D_2 = \frac{A_1}{A_2}$. The proper values for the resistance steps are then given by the equations (a) as before.

Case III. To find the proper values of the resistance steps for two motors in series started from rest.

Using the same symbols as above, plot the curve

$$y = \left[r\left(\frac{A_1}{A} - 1\right) + A_1\left(S_1 - S\right)\right] \times \left[1 + D + D^2 + \text{----} D^n\right]$$

Let I_2 be the value of I corresponding to $y = \frac{V - 2I_1 r}{I_1}$; S_2 the speed from the speed current curve corresponding to $I = I_2$; and A_2 the corresponding value of A; putting $D_2 = \frac{A_1}{A_2}$. The proper values for the resistance steps are then given by equations (a) except that $R_1 = r\left(\frac{A_1}{A_2} - 1\right) + A_1\left(S_1 - S_2\right)$

EXAMPLE

From a given motor speed curve the following values were taken:

$I_1 = 200$

$V = 600$

$r = .134$

$S_1 = 17.57$

Then the values of S corresponding to different values of I were read and the curve, $S_1 - S$, was plotted with I as abscissæ.

The values of D were computed and plotted on the same sheet, Fig. 1.

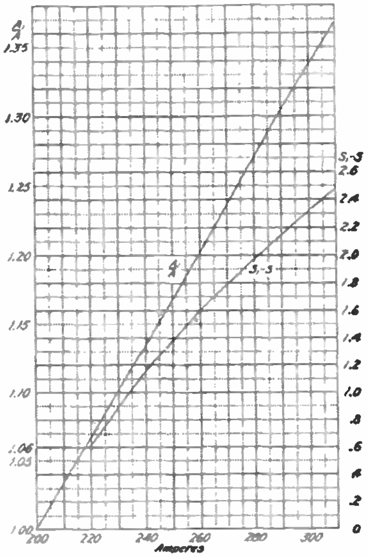

Fig. 1

In Fig. 2 were plotted the following curves for corresponding values of I and S.

$A_1(S_1-S)$ Curve (1)

$A_1(S_1-S)[1+D]$ Curve (2)

$A_1(S_1-S)[1+D+D^2]$ Curve (3)

$A_1(S_1-S)[1+D+D^2+D^3]$ Curve (4)

$A_1(S_1-S)[1+D+D^2+D^3+D^4]$ Curve (5)

$A_1(S_1-S)[1+D+D^2+D^3+D^4+D^5]$ Curve (6)

The computed values

$\frac{V-I_1r}{I_1}=2.866$ Case I

$\frac{V}{2I_1}=1.5$ Case II

were indicated at the margin.

CASE I

For a six point controller the ordinate 2.866 corresponds to a current $I_2=266$ on curve (6).

The ordinates for $I_2=266$ on curves (1), (2), (3), (4) and (5) are the values of the resistance steps.

$R_1=.28$

$R_2=.62$

$R_3=1.03$

$R_4=1.53$

$R_5=2.13$

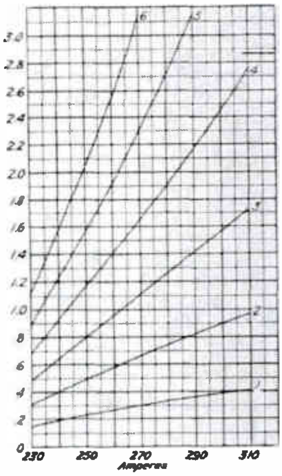

Fig. 2

Similarly for a five point controller the values are as follows:

$I_2=284$

$R_1=.33$

$R_2=.76$

$R_3=1.3$

$R_4=1.99$

Case II

The ordinate 1.5 corresponds to $I_2=230$ on curve (6). Therefore, for a six point controller, the values are

$R_1=.18$

$R_2=.39$

$R_3=.61$

$R_4=.88$

$R_5=1.17$

Similarly for a five point controller

$I_2=240$

$R_1=.22$

$R_2=.47$

$R_3=.77$

$R_4=1.12$

And for a four point controller

$I_2=265$

$R_1=.27$

$R_2=.61$

$R_3=1.01$

Also for a three point controller

$I_2=297$

$R_1=.37$

$R_2=.83$

Case III

For this case it is necessary to plot another set of curves corresponding to curves (1), (2), (3), (4), (5) and (6), which may be obtained by increasing the ordinates of curve (1) by $r(D-1)$ for each value of C, and of curve (2) by $r(D^2-1)$, of curve (3) by $r(D^3-1)$....and finally of curve (6) by $r(D^6-1)$.

The intersection of the computed value

$$\frac{V-2I_1r}{I_1}=2.73$$

with the new curve (6) gives a value I_2 the ordinates of which on the other curves are the values of the resistance steps for a six point controller.

Similarly the values of the resistance steps for five or four point controllers may be read at a glance.

THEORY

The counter e.m.f. of a motor is proportional to the product of the flux per pole and the speed. In a series motor the flux is a function of the line current, being approximately proportional to the current. Hence we may write the counter e.m.f.

$$E_c=ASI$$

where in general A is a factor depending on the value of the current. (If the reluctance of the magnetic circuit were constant, A would likewise be constant.)

Let r = resistance of motor.

V = voltage at which speed current curve is determined.

I_1 = any chosen value of the current.

S_1 = corresponding speed from speed-current curves.

A_1 = corresponding value of the factor A.

Then $E_c=V-I_1r=A_1S_1I_1$

$$\text{Whence } A_1=\frac{V-I_1r}{S_1I_1} \qquad (1)$$

Similarly, for any other value of the current

$$A_2=\frac{V-I_2r}{S_2I_2}. \qquad (2)$$

Now let

s = speed of motor with any given external resistance in series, at the instant the controller is advanced from one notch to the next.

I_1 = the current immediately before the advance.

I_2 the current immediately after the advance.

R = the external resistance before the advance.

R' = the external resistance after the advance.

Then

$$V=I_1(R+r)+A_1sI_1 \qquad (3)$$

$$V=I_2(R'+r)+A_2sI_2 \qquad (4)$$

But $V-I_1r=A_1I_1S_1$ and $V-I_2r=A_2I_2S_2$

Hence, substituting these values in (3) and (4) respectively, we get

$$A_1I_1S_1=I_1R+A_1sI_1$$

$$A_2I_2S_2=I_2R'+A_2sI_2$$

Dividing by A_1I_1 and A_2I_2 respectively

$$S_1 = \frac{R}{A_1} + s$$

$$S_2 = \frac{R'}{A_2} + s$$

Subtracting

$$S_1 - S_2 = \frac{R}{A_1} - \frac{R'}{A_2}$$

Whence

$$R = \frac{A_1}{A_2}R' + A_1(S_1 - S_2) \qquad (5)$$

Now let

$n+1$ = Number of steps on the controller.

n = number of blocks of resistance.

R_n, R_{n+1} ---- R_3, R_2, R_1 be the external resistances in order, R_n being the largest and corresponding to first point on the controller.

R_{n+1} = total external resistance required to hold the current at I_1 when the armature is blocked.

When the controller is advanced from the next to the last step to the last step, thus cutting out all external resistance, we have in equation (5) that $R = R_1$ and $R' = 0$. Hence

$$R_1 = A_1(S_1 - S_2) \qquad (6)$$

For the next preceding advance of the controller we have in equation (5) that $R = R_2$ and $R' = R_1$. Hence

$$\begin{aligned} R_2 &= \frac{A_1}{A_2}R_1 + A_1(S_1 - S_2) \\ &= \frac{A_1}{A_2}R_1 + R_1 \\ &= R_1\left[1 + \frac{A_1}{A_2}\right] \end{aligned}$$

Similarly

$$R_3 = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2\right]$$

$$R_n = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{------}\left(\frac{A_1}{A_2}\right)^{n-1}\right]$$

$$R_{n+1} = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{-----}\left(\frac{A_1}{A_2}\right)^{n}\right]$$

But for a *single* motor connected to the line, $R_{n+1} = \frac{V - I_1r}{I_1}$; hence I_2 must satisfy the condition that

$$\frac{V - I_1r}{I_1} = R_1\bigg[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{------}\left(\frac{A_1}{A_2}\right)^{n} \qquad (7)$$

where $R_1 = A_1(S_1 - S_2)$

Having *two motors* in full series taking a current I_1 is equivalent to having each motor connected directly to the line in series with an external resistance equal to $\frac{V}{2I_1}$. Hence if R_n is the external resistance for each motor corresponding to the first parallel notch on the controller, the equivalent resistance R_{n+1} corresponding to the next preceding notch is equal to $\frac{V}{2I_1}$. Hence for the parallel part of the controller period I_2 must satisfy the condition.

$$\frac{V}{2I_1} = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{------}\left(\frac{A_1}{A_2}\right)^{n}\right] \qquad (9)$$

Where

$$R_1 = A_1(S_1 - S_2)$$

For *two motors in series*, equations (3) and (4) become

$$V = I_1(R + 2r) + 2A_1sI_1 \qquad (3a)$$

$$V = I_2(R' + 2r) + 2A_2sI_2 \qquad (4a)$$

and from a similar course of reasoning as before, we get, instead of equation (5), the equation

$$R + r = \frac{A_1}{A_2}(R' + r) + A_1(S_1 - S_2) \qquad (5a)$$

The last resistance step is then

$$R_1 = r\left[\frac{A_1}{A_2} - 1\right] + A_1(S_1 - S_2) \qquad (6a)$$

Then as before

$$R_2 = R_1\left[1 + \frac{A_1}{A_2}\right]$$

$$\vdots$$

$$R_n = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{----}\left(\frac{A_1}{A_2}\right)^{n-1}\right]$$

$$R_{n+1} = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{----}\left(\frac{A_1}{A_2}\right)^{n}\right]$$

In this case, $R_{n+1} = \frac{V - 2I_1r}{I_1}$; hence for two motors in series I_2 must satisfy the condition that

$$\frac{V - 2I_1r}{I_1} = R_1\left[1 + \frac{A_1}{A_2} + \left(\frac{A_1}{A_2}\right)^2 + \text{----}\left(\frac{A_1}{A_2}\right)^{n}\right] \qquad (8)$$

Where

$$R_1 = r\left[\frac{A_1}{A_2} - 1\right] + A_1(S_1 - S_2)$$

400,000 VOLT TESTING TRANSFORMER

By John J. Frank

In the General Electric Review for December, 1904, the writer described two 150 kw., 160,000 volt testing transformers, which were built by the General Electric Company for the Columbia Improvement Company.

These machines were referred to at that time as being of exceptional design because of their high voltage rating. Recently a transformer designed for a much greater voltage has been shipped from the Pittsfield factory of the General Electric Company.

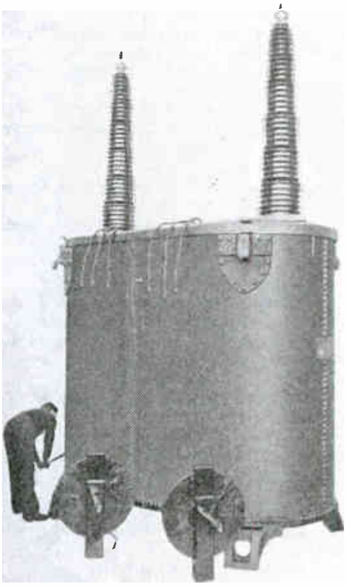

Fig. 1. 150 Kw., 400,000 Volt Testing Transformer

This transformer was built for the R. Thomas & Sons Company, of East Liverpool, Ohio, and is intended for the general testing of transmission line insulators manufactured by that concern.

Some idea of the size and construction of this transformer may be had from an inspection of the accompanying illustrations. Fig. 1 shows a view of the assembled transformer with the high tension coils and their supporting insulators on the outside, while Fig. 2 shows the completed transformer. This transformer is of 250 kw. capacity and is intended to operate at 60 cycles, with a primary voltage of 1150 or 2300 and a secondary voltage of 400,000. The low tension winding is wound directly on the core and in construction follows the usual practice for transformers of this description. The winding is provided with taps so that when connected for either 1150 or 2300 volts the center of the winding can be grounded. The high tension winding consists of a large number of circular disc coils, separately wound and insulated. A bare conductor is used and this is wound

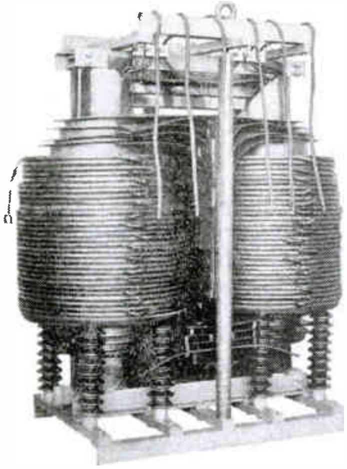

Fig. 2. Transformer Removed from Case

one turn per layer and placed between the selvaged edge of the intervening insulation, thereby making it practically impossible for any of the turns to become displaced. These coils are then taped and impregnated with insulating compound, with the result that the coil forms a solid mass of insulation and winding. This method of constructing the coils has been generally adopted for transformers of high voltage, since it has given universal satisfaction wherever used and makes possible the designing and building of a transformer that will operate satisfactorily at high voltage, such as that at which the transformer under consideration is intended to work.

As shown by the photograph, the high tension winding is supported by sectional porcelain insulators, and between the primary and secondary windings are placed concentric cylinders with flanged ends. Between these cylinders vertical and horizontal ducts are arranged to allow for the circulation of the oil, thus providing sufficient creepage surface to prevent any appreciable leakage from the high tension winding to ground.

The high tension transformer leads are similar in design to the usual high tension leads; in other words, consist of sectional leads filled with oil.

The cover of the transformer is of cast iron and is provided with a manhole to facilitate examination and inspection of the interior of the transformer. The necessity of disturbing any of the external connections is thus avoided.

One of the tests to which this transformer was subjected before shipment was a one-half hour run at 650,000 volts, with the center of the high tension winding grounded. It has also been tested with first one and then the other of the high tension terminals grounded and the winding excited at 400,000 volts.

Within the last year a considerable number of transformers of similar design, ranging in voltage from 150,000 to 300,000 volts, have been built and tested, but, so far as is known, this transformer operates at a higher voltage than any other which has been built for commercial work.

The general characteristics of the transformer are as follows:

Core loss	8400 watts
Copper loss	1270 watts
Total	9670 watts
Efficiency, full load . . .	96.3 %
Exciting current	7.18%
Impedance	5.4 %
CR drop	0.51%
Reactance	5.4 %
Floor space . .	5 ft., 7½ ins. by 10 ft.
Height to top of lead	16 ft., 9¼ ins.
No. gallons of oil	2270 gals.
Net weight .	20,000 lbs.

BOOKS RECEIVED

The GENERAL ELECTRIC REVIEW has recently received the following books, reviews of which will be published later; these works, together with those previously received, may be examined at the REVIEW office:

Ball, Sources of Power.
Bedell, Direct and Alternating Current Testing.
Blaine, Calculus and Its Applications.
Bottone, Magnetos for Automobilists.
Brewer, The Motor Car.
Bright, Life of Charles Tilson Bright.
Carpenter & Diederichs, Combustion Engines.
Davies, Electric Power and Traction.
Del Mar, Electric Power Conductors.
Fowle, Protection of Railroads from Overhead Transmission Line Crossings.
Groth, Welding and Cutting Metals by Gases or Electricity.
Gueldner, Combustion Engines.
Hobart, Electricity.
Hobart, Heavy Electrical Engineering.
Hogle, International Combustion Engines.
Koester, Hydroelectric Developments & Engineering.
Koester, Steam-Electric Power Plants.
Sloane, Elementary Electrical Calculations.
Solomon, Electric Lamps.
Sothern, The Marine Steam Turbine.
The Copper Handbook, Vol. IX.

PREVIOUSLY RECEIVED

Ashcroft, Study of Electrothermal & Electrolytic Industries.
Auerbacher, Electrical Contracting.
Barrows, Electrical Illuminating Engineering.
Bowker, Dynamo, Motor and Switchboard Circuits.
Franklin & Esty, Elements of Electrical Engineering.
Kershaw, Electro-Metallurgy.
McAllister, Alternating Current Motors.
Monckton, Radio-Telegraphy.
Russell, Electric Cables & Networks.
Taylor, Stationary Transformers.