backfill. This work at Pedro Miguel was completed in July, 1916, and at Miraflores in May, 1917.

Turnouts.—During the year the turnouts for Miraflores locks were completed, those for Pedro Miguel lock having been completed during the previous fiscal year.

Towing locomotives.—Two new towing locomotives were received in June, 1917, from the mechanical division, which division performed the mechanical work on them; the electrical work is being done by the lock forces.

Backfill.—The grading of the west backfill at Pedro Miguel lock was completed in April, 1917, approximately 15,500 cubic yards of material having been removed, at an approximate cost of $7,000.

Electrical Division.

The duties of the electrical division have continued the same as last year.

The power plants, substations, transmission and distribution systems have operated satisfactorily without incident worthy of special mention.

New 4,400-horsepower water wheels were installed at the Gatun hydroelectric station in units 1, 2, and 3, which has increased their capacity about 40 per cent, making a total for the station of 8,640 k. w. at 80 per cent power factor. Money is available, material has been ordered, and construction is under way for the installation of three additional penstocks and one additional unit (No. 4) of 4,500 k. w., which was as large as could be installed without radical changes in building layout. The operating voltage will be changed to 6,600 volts. Provision is being made for the addition of units Nos. 5 and 6 whenever they are required. The capacity of the hydroelectric station, when present changes are completed, will be 13,140 k. w., and this has necessitated corresponding changes in transformers, etc. The ultimate capacity of the hydroelectric station as now contemplated will be 22,140 k. w., which is about double our present load and about 50 per cent over-all load immediately in prospect.

Our estimates indicate that there will be sufficient water over and above that necessary for the maximum capacity of locks and for other necessary purposes to provide for this power except during an abnormally dry season, during which time it is expected to carry the load at Miraflores steam plant.

The Miraflores steam plant now consists of six steam-driven turbogenerators, each of 1,200 k. w. capacity at 80 per cent power factor. It is expected to operate this plant as a reserve for the hydroelectric station in case of accident or whenever necessary to save water. As far as can be foreseen at present, it will be more economical to maintain our reserve at this plant rather than by new hydro projects elsewhere. It will be necessary to increase the capacity of the steam plant, and estimates are now being prepared to do this work in the fiscal year 1919.

The average production cost of current for power, exclusive of depreciation at 3 per cent, was $0.005106 per k. w. h., and including depreciation charges was $0.007301 per k. w. h. The average cost of current for lighting, which includes maintenance of house and building lighting systems and lamp renewals, was $0.01338 per k. w. h.

There were 38 cases of power interruptions and 27 insulator failures, as against 33 and 27, respectively, for the previous year. Plans are under way and funds are available for the installation of a fourth disk on insulators and for installation of reverse current relays for operation of transmission lines in parallel during the coming year.

About 185,000 feet of underground cable were laid, and complete lighting systems were installed in 86 Army buildings, 45 Panama Railroad buildings, and 991 apartments for canal employees.

On the railway signal system there was only one reported false clear aspect, and considerable improvement has been made in lessened signal interruption and train delays compared with previous years.

There were 2,154 telephones in service on June 30, 1917, as against 1,878 on June 30, 1916. The average number of cases of telephone trouble per day has been reduced from 13 to 8. New storage batteries were installed at Colon, Pedro Miguel, and Balboa exchanges. Plans are under way to take care of increase in telephone business by building a new exchange at Cristobal and installing additional cable for trans-isthmian service.

The fire-alarm system has been incorporated in the telephone department.

The details of the operations of the electrical division during the fiscal year are covered in the report of the electrical engineer, which follows:

Electrical Division.

Maj. T. H. Dillon, United States Army, Electrical Engineer.

The duties of the electrical division during the fiscal year comprised the necessary work of design, construction, operation, and maintenance of the steam and hydroelectric power plants, substations, transmission lines, and power-distribution systems; municipal, street, dock, building, and house lighting systems; the telephone, telegraph, fire-alarm, and railway block signal systems and interlocking plants; the electric cargo-handling cranes; electric-truck storage-battery systems; and the installation and repair of all classes of electrical apparatus for The Panama Canal, Panama Railroad Co., Army, and Navy, and of all departments and divisions therein.

ORGANIZATION AND PERSONNEL.

Maj. W. H. Rose was electrical engineer until June 1, 1917, upon which date he was relieved by Maj. T. H. Dillon. On November 29, 1916, the work was divided into five principal divisions, as follows: Office and requisitions, Carl W. Markham; power and transmission system, W. L. Hersh, superintendent; construction and maintenance, W. L. Fey, superintendent; telephones and telegraph, C. L. Bleakley, superintendent; railway signal system, E. C. McDonald, supervisor.

On June 30, 1917, there were 198 gold and 483 silver employees on our rolls. Our average monthly expenditures are about $85,000, of which $72,000 consists of work done for other departments and divisions.

OFFICE AND DESIGN.

The usual miscellaneous office work was done throughout the year, including correspondence, requisitions, reports, etc.

Plans were developed and specifications prepared for the extensions to the hydro plant for more than doubling its capacity; for necessary changes to our power and transmission systems resulting therefrom; for necessary extension to underground conduit and cable distribution systems for light, power, and telephone systems in permanent towns and Army and Navy reservations, and for all new buildings of The Panama Canal, etc.

This division has been assisted in large measures in design and specification by the office engineer, Mr. C. J. Embree, and the draftsmen under his charge, to all of whom great credit is due.

REPORT ON ELECTRICAL POWER.

Electrical power was furnished for the construction of the canal by steam plants at Gatun, Empire, and Miraflores. The hydroelectric plant at Gatun was designed to replace these plants for furnishing continuous power upon the completion of canal construction work. The original installation at the hydro consisted of three 2,000 k. w. generators at 80 per cent power factor.

The Miraflores steam plant was continued in service as a reserve plant, and to it were transferred the units from the Gatun steam station. The Miraflores steam plant now consists of six steam-driven turbines direct connected to 1,200 k. w. generators working at 80 per cent power factor and tied into the high-tension transmission line through the Miraflores substation. Sufficient power is held in reserve to supply Pacific locks in case of failure of service elsewhere, and two boilers are kept under pressure for ready service.

Due to the steady growth of the electrical load on the Isthmus, as discussed in previous reports, the original capacity of the hydro station was insufficient, and peak loads were carried at Miraflores steam plant. New water wheels were installed at Gatun, as discussed in report of 1915 and 1916, which has increased the capacity of each of the three generators to 2,880 k. w. at 80 per cent power factor, an increase in power of approximately 40 per cent. This work was completed December 19, 1916, at a total cost of $16,377.91. This includes credit for bronze runners removed and sold as scrap.

The next step contemplated the extension of the building and the installation of three more units. This work is now under way. Only one new unit is being installed at the present time. In connection with this extension it was decided to raise the voltage of the three origial units at the station by autotransformers and make the operating voltage 6,600 on account of saving thus accomplished in cost of necessary cables from hydro to Gatun substation. The new unit was designed for the greatest capacity that could be gotten into the building without radical changes. It consists of a General Electric Company 6,600-volt, 3-phase, 25-cycle, 4,500 k. w. (at 80 per cent power factor) generator mounted on vertical shaft connected to 6,750 h. p. turbine furnished by the Pelton Waterwheel Company.

Provision had been made in the original plans for three additional penstocks, and these are now being installed, so that future increases will consist of purchase of new generating units and necessary switches, transformers, etc., only.

On June 30 the foundations, concrete draft tubes, etc., had been placed and erection of penstocks about 10 per cent completed. Contracts have been let for the necessary equipment.

After the installation of the new unit there will be available at the hydro station a capacity of 13,140 k. w., with provision for future installation of two more units of 4,500 k. w. each, making the ultimate capacity of the hydro station 22,140 k. w. This capacity will provide for about double the present load and will also provide about a 50 per cent reserve over and above any increases in load now contemplated. Further increase in capacity would require radical change of station layout and would involve a prohibitive expense.

It should be kept in mind that additional power can probably be produced at the Miraflores steam plant more cheaply than by a new project at Gatun hydro station or by new hydraulic developments elsewhere, such as at Alhajuela or Miraflores.

With respect to available water supply for power purposes, it is estimated that with all six units installed at the hydro plant and operating at about 70 per cent load factor there will be required approximately 2,600 cubic feet per second.

It is expected to continue the Miraflores steam plant as a reserve and to keep its capacity at about two-thirds that of the hydro station. This will necessitate an increase in capacity there in the near future, for which estimates will be submitted for 1919.

The total connected load at the end of the year was approximately 55,372 k. w. in power and heat and 5,744 k. w. in light.

The load factor is approximately 70 per cent and the demand factor is approximately 15 per cent.

The principal loads (in k. w.) added during 1917 were:

	Power.	Light.
Balboa coaling station	1,267	100
Army quarters and buildings	.....	100
Employees quarters	400	300
Dry Dock No. 1, Balboa	6,040	10
Air compressor plant, Balboa	1,600	3
New hospital, Ancon	30	25
Cold storage and ice plant, Balboa	450	8
Laundry, Ancon	100	20
New restaurants, Balboa and Cristobal	20	8
New dispensary, Ancon	5	10
New schools	.....	20
Miscellaneous municipal buildings	.....	200
Other miscellaneous items	1,000	500
Total	10,912	1,304

The known loads to be added in future are:

	Power.	Light.
Series street lighting systems	.....	100
Submarine charging station and aviation	3,000	100
New cold storage plant, Cristobal	1,800	20
New town sites	200	400
Storage battery charging station, Cristobal	150	.....
Pacific forts	245	155
Miscellaneous municipal buildings	100	100
New air compressor plant, Balboa	1,000	.....
New air compressor, Cristobal	500	.....
Permanent Army posts	.....	800
New piers	200	300
Total	7,195	1,975

Table showing monthly outputs in kilowatt hours:

Month.	Net output in kilowatt hours.		Total net generated power.	Per cent loss in transmission based on total delivered power.
	Gatun hydro station.	Miraflores steam station.		
1916.				
July	3,672,750	+153,090	3,825,840	12.56
August	3,900,890	+291,444	4,192,334	14.25
September	3,319,860	+389,280	3,709,140	13.9
October	3,455,470	+475,840	3,931,310	13.5
November	4,028,220	+212,480	4,240,700	14.85
December	4 130,640	— 55,285	4,075,355	16.6
1917.				
January	4,235,000	−133,140	4,101,860	13.7
February	4,282,400	−152,135	4,130.265	14
March	4,582,100	−141,860	4,440,240	14.6
April	4,401,600	— 79,650	4,321,950	14.2
May	4,810,400	— 40,790	4,769,610	16.8
June	4,772,300	−122,640	4,649,660	16
Average	4,132,620	.....	4,199,020	14.6

NOTE.—Miraflores steam station is run as a reserve station and one generator is always floated on the line to automatically pick up load. It runs most of the time as an overexcited synchronous condenser for power-factor correction.

The following table shows the cost of power in its various states of distribution. Cost figures are based on delivery to consumer and not on the net amount actually generated.

	Totals for fiscal year 1916–17.	Average per month.	Average cost per kilowatt hour.
Net consumption (kilowatt hours)	43,743,902	3,645,325	.....
Cost of operation and maintenance, hydro station	$27,525.80	$2,293.82	$0.000629
Cost of operation and maintenance, Miraflores steam plant	72,405.07	6,033.76	.001655
Cost of operation and maintenance of substations	52,629.30	4,385.77	.001203
Cost of maintenance, transmission lines	19,965.11	1,663.76	.000456
Cost of maintenance, distribution lines	50,866.59	4,238.88	.001163
Depreciation, transmission system	96,000.00	8,000.00	.002195
Total cost of current for power distribution	319,391.87	26,615.99	.007301
Net consumption, lighting current (kilowatt hours)	8,245,912	687,159	.....
Cost of maintenance, house-lighting system, including lamp renewals	$50,129.40	$4,177.45	$0.006079
Cost of lighting current per kilowatt hour	.....	.....	.013380

Plate No. 2 shows the average and maximum loads in kilowatts for the week ending June 30, 1917, as compared to the same period in 1916.

SUBSTATIONS AND TRANSMISSION LINES.

The substations operated satisfactorily during the year. There were no failures of high-tension service due to failure or improper operation of substation apparatus.

The following changes and additions to equipment have been made:

Transferred one 2,667 k. v. a. 44,000-volt transformer from Gatun substation to Cristobal substation and installed two 4,000 k. v. a. 44,000-volt transformers at Gatun substation. This increased the capacity of Cristobal substation from 5,334 k. v. a. to 8,001 k. v. a. and of Gatun substation from 8,001 k. v. a. to 13,334 k. v. a.

One additional feeder equipment was installed in Balboa and one in Cristobal substations to provide for new outgoing 2,200-volt feeders.

The operation of the 44,000-volt transmission line has been fairly satisfactory. Plate No. 3 shows the number and causes of power interruptions during the year. Plate No. 4 shows the locations and dates of insulator failures during the year.

Since April 2, 1917, the spare transmission line has been kept charged at all times.

Plans are under way for the installation of a fourth disk on each insulator and for the operation of the transmission lines in parallel.

There were 3 cases of ground wire breaking during the year, as compared with 10 in 1916 and 13 in 1915.

DISTRIBUTION LINES.

There were two interruptions to service during the year, due to defects in the distribution system cable, one being caused by moisture in a piece of 2,500-volt 3-conductor, lead-covered cable, and the other caused by the parting of the submarine cable supplying power to Fort Sherman.

A total of 185,624 feet of new cable of various sizes and voltages was laid during the year; 38,510 duct feet of fiber duct and 78,672 duct feet of vitrified tile duct were placed, covering extensions to the system to provide for new town sites and various power and light loads added or increased during the year. The 2,200-volt overhead feeder from Miraflores substation to Paraiso was removed, leaving a 11,000-volt overhead line feeding the Army camps on the west side, and the dredging division relay pumps in the Cut, a 2,200-volt overhead line feeding the Balboa relay pumps, and some overhead lines at Mount Hope used for miscellaneous installations as practically the only overhead lines left in service, all the main distribution systems being underground.

Complete lighting systems were installed in 86 Army buildings, 45 Panama Canal and Panama Railroad buildings, and 991 apartments for gold and silver employees during the year. All wiring was laid in galvanized-iron conduit, both in concrete and frame buildings, and substantial fixtures were used throughout. Following are some of the principal items used in this work; 624,585 feet of conduit, galvanized iron, all sizes; 294,731 conduit fittings, galvanized iron,