

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. W. H. Rose, Electrical Engineer.*

During the fiscal year the duties of the electrical division comprised the operation of all steam and hydroelectric power plants, Balboa air-compressor plant, electrical transmission and distribution systems for The Panama Canal; the design, construction, operation, and maintenance of permanent underground electrical distribution systems, street-lighting and house-lighting systems for The Panama Canal, Panama Railroad, Army and Navy; the operation and maintenance of the telephone, telegraph, and automatic railway-signal systems and of the electric cargo-handling cranes for the Panama Railroad; the installation, operation, maintenance, and repair of electrical apparatus of all kinds for other departments and divisions of The Panama Canal.

#### DIVISION OFFICE AND DESIGNING WORK.

The usual office work was done throughout the year in connection with miscellaneous correspondence, reports, power and compressed air accounting, and other routine papers. Plans were developed and specifications prepared for new water turbines of increased size (4,400 h.p.) for the three main generating units of the Gatun hydroelectric station, for four new cable feeders of 400,000 circular mil conductor area between the hydroelectric station and Gatun substation, for two new 4,000 k.v.a. power transformers for Gatun substation, and for new oil switches and other accessories for both the hydroelectric station and Gatun substation to provide for the increased equipment above named. The necessary plans, estimates, specifications, requisitions, etc., were prepared for extensions to underground conduit and cable distribution systems for electric light, power, telephone, street lighting, and fire alarm service in permanent towns and Army posts, for lighting and power systems in all new buildings for The Panama Canal, Panama Railroad, United States Army, and United States Navy, and for light and power systems in new Pier No. 18 at Balboa and new laundry at Ancon.

#### OPERATION OF POWER PLANTS.

*Hydroelectric station.*—The hydroelectric station at Gatun has been in continuous operation throughout the year as the primary source of power for all purposes in the entire Canal Zone. There have been no operating difficulties worthy of mention, and the operating characteristics of all machines and apparatus has been highly satisfactory throughout the year.

**Due to the steady growth of the electrical load on the Isthmus**, as discussed in the last annual report, the present capacity of the hydroelectric station is insufficient to meet the demand at all times, and during the fiscal year it has been regularly necessary to carry peak loads ranging up to 2,000 kilowatts and of several hours duration per day on the steam generating station at Miraflores. The plan of increasing the capacity of the hydroelectric station by the installation of new and higher capacity water turbines on the present generators was discussed in detail in the last annual report. The new water wheels have been on order since January 21, 1916, and delivery is now overdue by over a month, but is expected within the next few weeks. This change in the size of the turbines will result in increasing the capacity of each of the three units from 2,000 kilowatts to 2,880 kilowatts at 80 per cent power factor, an increase of approximately 40 per cent.

Even with this increase it now appears certain that the capacity of the hydroelectric station will again be exceeded in the near future by the addition of the following loads:

	Kilowatts.
Balboa Dry Dock pumps.....	<sup>1</sup> 4,500
Balboa Dry Dock light and power.....	150
Balboa coaling plant.....	750
Balboa town addition.....	150
Balboa submarine base.....	500
Ancon laundry.....	150
Ancon Hospital.....	225
Cristobal coaling plant.....	<sup>2</sup> 2,000
Cristobal cold-storage plant.....	300

<sup>1</sup> Intermittent.

	Kilowatts.
Cristobal town addition.....	50
New Pier No. 6.....	200
Stoves, water heaters, and other domestic appliances.....	1,500
Additional air compressor, Balboa.....	1,000
Pacific fortifications.....	225
Coco Solo submarine base.....	1,000
Additional Army quarters and storehouse.....	150
Total.....	12,845

The above loads are estimated only, but are believed to be low rather than high. Due to the effect of the load factor, the value of which can not be predicted, these loads will not produce a combined load on the system equal to the total of their separate values. The combined load, however, of these various increases will certainly be sufficient to raise the total demand on the Canal Zone beyond the capacity of the present generating equipment in the hydroelectric station even after the new wheels are installed.

For this reason funds were requested in the estimates for the fiscal year ending June 30, 1917, and have been appropriated for building an addition to the present station building large enough to provide for three additional generating units with their auxiliaries and for installing the first one of these three units. At the time the estimate was made it was intended that the new unit should be of the same size as the present ones with the new wheels, namely, 2,880 kilowatts at 80 per cent power factor. This would result in a station capacity of 11,520 kilowatts after the first new unit is installed and in an ultimate station capacity of 17,280 kilowatts. In case future developments on the Canal Zone increased the demand beyond this last amount, further increase at the hydroelectric station could only be secured at the expense of extraordinary difficulties and costs on account of the construction of the dam and spillway. Investigation has shown, however, that at slightly increased cost at the present time, and with only minor modifications in the interior design of the present station building, provision can be made for making all three of the new generating units of 4,500 kilowatts capacity, which will result in an ultimate station capacity of 22,140 kilowatts, instead of 17,280 kilowatts if present sizes are adhered to. Plans are therefore proceeding in the way of designs for penstocks, building, exciters, and other accessories on the assumption that the new unit to be purchased during the fiscal year 1917 will be of 4,500 kilowatts capacity at 80 per cent power factor, and that the two future units will be of the same size. The growth of the electrical load on the Isthmus has been so rapid and the experience of all electrical utility companies in the United States is so conclusive as to the certainty of continual growth that it is believed to be unquestionably the wisest policy to provide at the present time for the largest ultimate capacity that can be attained without radical and very expensive changes in the existing installation. The plan outlined above makes this provision.

Investigation has also shown that a very material saving in the ultimate cost of the power system can be effected if the new units are designed for generating at 6,600 volts instead of 2,200 volts, as in the case of the present units. The voltage of the present units will be stepped up to 6,600 volts by auto transformers to be installed between the generators and the station busses.

A typical load curve showing the combined load on both the hydroelectric station and Miraflores steam plant is shown on plate No. 68. The lower curve shows the average combined load at each hour of the day for the seven working days, June 23, 24, 26, 27, 28, 29, and 30. The upper curve shows the maximum combined load at each hour for the same seven days.

The production cost of current delivered from the switchboard of the hydroelectric station during the fiscal year was 0.06 cents per kilowatt hour. This cost includes all operation, maintenance, and division overhead charges, but does not include a charge of 3 per cent per annum of the capital cost of the entire power system that is being charged into our monthly accounts against the cost of power to cover functional depreciation. For convenience in accounting the depreciation of the entire system, including transmission lines, substations, and distribution systems, is charged into the cost of power at the generating station. If this depreciation charge be included, the cost of power at the hydroelectric station for the fiscal year was 0.27 cents per kilowatt hour.

The operation and maintenance of Gatun spillway was conducted during the year by the hydroelectric station force. All baffle piers were repaired during the last dry season, marked erosion of these piers having been noted in last year's annual report. Two additional cast-iron face plates were installed on each pier to protect the faces on

which erosion was most marked, and floor plates were installed to prevent further attack in the angle between pier and floor. The changes have made some improvement in conditions, but do not yet afford the desired degree of protection, and further work will have to be done during the next dry season.

*Miraflores steam station.*—This station has been operated as a reserve plant during the fiscal year, several boilers being kept under steam and up to pressure at all times, so as to minimize the length of interruptions in the case of failures at the hydroelectric station or on the transmission line. It has also regularly assisted the hydroelectric station by carrying peak loads whenever the total load was greater than the capacity of the latter plant. One or two of the 1,500 k.v.a. turbo generators have been kept "floating" on the line at all times in order to improve the regulation of the transmission line by improving the power factor by operation as synchronous condensers, and in order to be in immediate readiness for service in case of emergencies.

The amount of power absorbed by the plant in the operation of generators as synchronous converters, excitation, lighting, etc., has actually exceeded the power output during the year, so that no costs for generated power can be given.

The addition to the station building mentioned in last year's report for enabling the remaining equipment to be transferred from the Gatun steam station was completed during the year at a cost of \$47,268.90. All equipment has been removed from the Gatun plant and the old power plant building taken down. The work of reinstalling the equipment in the extension at Miraflores and of making the electrical changes necessitated by the extension was approximately 90 per cent completed at the close of the fiscal year, and the cost of removing from Gatun, reerecting at Miraflores, and making necessary electrical changes was \$33,703.81 up to June 30, 1916. The following tabulation shows monthly net outputs during the fiscal year from the hydroelectric station and Miraflores steam station, monthly costs of generated power, not including depreciation, power actually distributed to consumers, and per cent loss of power in transformation, transmission, and distribution:

Month.	Kilowatt hours.		Cost of generation, cents per k.w.h.		Total generated power.	Total delivered to consumers.	Per cent loss in transformation, transmission, and distribution.
	Gatun hydro-station.	Miraflores steam station.	Hydro-station only.	Including Miraflores.			
1915.							
July.....	2,957,000	23,000	0.06	0.20	2,980,000	2,522,195	19.0
August.....	3,185,680	14,480	.07	.18	3,200,160	2,683,143	19.3
September.....	3,209,680	—23,250	.06	.17	3,184,430	2,721,078	17.1
October.....	3,391,130	—17,130	.06	.18	3,374,000	2,805,006	20.3
November.....	3,252,142	—79,870	.07	.20	3,172,272	2,044,683	20.0
December.....	3,345,410	—80,030	.06	.19	3,265,380	2,663,697	20.6
1916.							
January.....	3,261,000	—81,220	.06	.18	3,179,880	2,673,071	18.2
February.....	3,211,690	27,000	.06	.17	3,238,690	2,652,649	22.1
March.....	4,001,200	53,470	.05	.12	4,054,670	3,521,572	15.1
April.....	3,438,300	—41,970	.06	.19	3,396,330	2,896,148	17.3
May.....	3,757,050	43,890	.06	.18	3,800,940	3,317,344	14.6
June.....	3,526,160	87,490	.06	.16	3,614,450	3,086,175	17.1
Average for the year.....			.06	.17			

#### AIR-COMPRESSOR PLANT.

The steam-driven air-compressor plant was operated during the fiscal year until April 18, 1916, for the supply of compressed air for Balboa shops, dry-dock and terminal construction, Sosa Hill quarry, and other purposes. On this date the plant was shut down and immediately dismantled.

The following tabulation shows the monthly output of this plant, in cubic feet, of free air compressed to 105 pounds per square inch:

	Cubic feet.
1915.	
July.....	157,805,925
August.....	169,328,705
September.....	156,993,290
October.....	173,676,645