

the shore end was $4\frac{1}{4}$ inches in diameter and weighed approximately 22 pounds per foot. The weight of the cable and the reel was approximately 15 tons, and the combined weights of the messenger cables, power cables and the reels approximated 380 tons. Incidentally, it required 15 flat cars to transport the entire shipment from the factory.

Cable Terminals and Anchorages.—For a distance of 30 feet from the Marin shore the power cable was not attached to the messenger, but was conducted through a channel which had been dug through the rock. From this position, moreover, the cable was housed in an iron pipe and completely embedded in the water at the shore line to protect it from wave action. As mentioned heretofore, the bluff on this shore is very steep, and it was on this account necessary to erect along the face of the bluff a series of concrete pillars approximately every ten feet. To these piers a channel iron was fastened, and to this were clamped the cable and a cover of heavy galvanized iron. At the top of the bluff the cable was laid in a concrete trench beneath the ground line.

Cable-Laying Equipment.—The barge used in the laying of the cable was of 125 tons capacity, 70 feet long, with a beam of 30 feet, and when loaded had a freeboard of about 5 feet. When laying the messenger the axis of the reel was parallel to the short axis of the barge, and a 100 horse-power launch was used for towing. The same barge was used when laying the cable, but the cable reels were mounted with their axis parallel to the long axis of the barge; in this way the barge was least affected by the prevailing action of the tide and the waves in the channel. The tow for the cable-laying equipment was a 50 horse-power launch. However, during very heavy tide run, two launches were necessary for towing the equipment.

On both sides of the barge grooved cast-iron sheaves, 40 inches in diameter, were securely fastened to the deck, a rigging being provided to prevent the messenger cable from leaving the sheave, no matter what position the barge might take. The cable was fed from the reels around rolls through the serving machine, together with the messenger cable, the two being tied together by the machine in question.

This serving machine, which was driven by a gasoline engine, consisted of two circular iron rings mounted in an iron frame, the rings being made to revolve by a friction drive so arranged that the machine could be stopped or started by the movement of a handle. Removable jaws in the cast-iron rings were provided so the machine could be slipped over the cable and the messenger.

Two spools of No. 6 galvanized iron wire were held between the rings and the outer edges. In this way when the cable and the messenger were allowed to travel through the serving machine, the rings were made to revolve and the machine would wind around the cable and the messenger a serving of the two wires.

Every 20 feet the movement of the barge was stopped by means of the grip and a considerable number of turns wound around the cable and the messenger at one point. This was done to secure the attachment of the cable to the messenger at least every 20 feet in the event of the breaking of the serving wires between these wraps. Formerly the work of serving was done by hand entirely, and was a slow and tedious process. However, with the development of the serving machine for this installation the work was greatly facilitated and much better performed. The speed of cable laying was about 8 feet per minute.

The Joint.—After a length of cable had been laid out, the messenger was made fast in the grip on one side of the barge, while on the other side the messenger and the cable were lashed to the sheave, and the joint made with the next reel of cable. This being done, the serving machine was again brought into action as before, except that the serving wires were now fed through slotted bars attached to one side of the circular revolving cast-iron rings.

Since the barge was held fast to the messenger, the serving machine was mounted on rollers, and as the serving wires were laid over the joint, the machine forced itself along. Every twelve inches the serving wires were soldered together to protect against the wire unwrapping for any distance in case of its breaking. Here again the serving machine accomplished in one hour the work that was formerly done in eight hours by hand.

After the joint had been served it was carefully paid overboard, every effort being used to protect it against undue strains. The cable was not attached to the messenger for a distance of about 8 feet on each side of the splice, and thus the splice was allowed freedom of movement independent of the messenger. With prevailing wind and tide conditions it required on an average 24 hours to pay out one length and to make a splice. There were 11 splices for each completed cable.

Laying the Last Length.—Cable laying was continued in the manner described until within approximately 800 feet of the shore, at which point the cable was sealed, attached to the messenger, and dropped overboard. The barge was then towed to shore and turned around, after which the messenger was again picked up and the shore end pulled into the beach. After the shore end was made fast cable laying was resumed, the shore end being paid out until the end that was dropped overboard appeared. At this point, the final splice was made; the cable and the messenger were then underrun to a point midway between the two splices, hoisted over the reels and then gradually lowered to the bottom by means of ropes. This method was pursued, since it was the easiest way by which the shore end could be handled. Furthermore, there was no difficulty in handling this because enough slack had been left near the shore to allow hoisting overboard as above described.

Progress of the Work.—As the prevailing trade winds and fogs are at their worst during the summer months, and as the winter storms usually commence early in December, it was necessary to prosecute the cable laying during the months of September and October. All equipment being provided and having consulted all tide tables, the first messenger was laid on the morning of September 18th, 1915. Laying of the power cable was commenced September 26th and was finished on the afternoon of October 7th. The work on the second cable was started October 16th and completed and tested on October 30th.

Extremely heavy tide runs occasioned considerable trouble, the force of the tide being strong enough to cause the messenger to slip in the temporary anchors while the barge was near the centre of the channel. This indicated that the force of the tide was sufficient to move the messenger cable, which between bar and shore amounted to a weight of twelve tons, in addition to the friction of the cable on the sandy bottom and the holding power of the temporary clamps. In the meantime work on the terminal house and the land cable connections was being rushed, and the tie-in between sub-station "F" and the submarine cables was completed and the voltage applied from San Francisco on November 5th.