The Largest Electric Water Power Station in New Hampshire.—I.

MOSES G. FARMER said that Garvin's Falls would one day supply light and power in Manchester, N. H., fourteen miles distant, when he was in that city many years ago. This prophecy has now come true. During 1902 an electric station was built at Garvin's Falls, and energy from the falling water began to be transmitted to Manchester at about 12,000 volts pressure, as described in the ELECTRICAL WORLD AND ENGINEER of January 17, 1903. At that time the capacity of the electric station was 1,300 kw, and the water was made available at the station by a previously existing dam and canal.

This dam is decades, and the canal perhaps a century, old. In that portion of its bed opposite to the canal, the Merrimac River passes over a series of rapids or low falls, and the old canal appears to have been built at first as an aid to navigation between Concord, New Hampshire and Boston. In 1793 a charter was granted for the construction of a canal between the Charles River and Lowell, on the Merrimac River. About the same time the Bow Lake and Canal Company secured a charter with the right to perfect navigation south of Concord on the Merrimac River. This stream passes over a number of falls and rapids between Concord and Lowell and the remains of an old canal can be traced at a number of such points along the river. Just when the canal through which boats passed around Garvin's Falls came into use cannot now be stated, but Hayward's *New England Gazetteer*, published by John Hayward at Boston, in 1839, mentions the canal as an important waterway for boats coming south from Concord.

The railways having put an end to water traffic on the Merrimac, attention was turned to Garvin's Falls as a source of power, and a stone dam was completed there near the upper end of the old canal, on September 5, 1859. The final builder of this dam, being in a hurry to complete it, dumped a large amount of loose rock in to form the central portion, after the builder of the end sections had been called to Washington to superintend work on a new government building there. As might have been expected, the dam failed in the freshets of the following year, about 200 ft. of the central portion going out on March 5, 1860. The dam remained in this partly

FIG. 1.—OLD DAM AND CANAL, GARVIN'S FALLS.

ruined condition for nearly a score of years, or until 1879, when its owners filled up the central gap with a timber crib and stone section just in time to prevent the lapse of their flowage rights.

At the time when a location was being sought for some of the large cotton mills now at Lowell, the site at Garvin's Falls was considered, but finally rejected. Thus the small tower of Bow, where the falls are located, escaped the fate of being a large city. From the rebuilding of the dam in 1879 down to about 1890 the water power at Garvin's Falls appears to have been used to some extent and during a portion of the time for local manufacturing purposes. Some time after the latter date an electric lighting station of small capacity was built there for comparatively nearby service, and this lighting plant remained until after the property passed into the hands of the Manchester Traction, Light & Power Company, near the close of the century. From all this it appears that although these falls had been close to places of considerable population for a hundred years, and a dam and canal had been maintained for power purposes during forty years, yet most of the energy of the water had run to waste during these long periods. It remained for electrical transmission, answering the demands of the largest city in the State, to bring Garvin's Falls effectively into the service of men.

Shortly after the purchase of the Garvin's Falls property by the Manchester company, the new electric station of 1,300-kw capacity, above named, was built, and the transmission at 12,000 volts to that city begun. This new station relied for power on the patched dam of 1859, and on the transportation canal that ran back into the eighteenth century for its origin. Though the Manchester company had

FIG. 2.—OLD AND NEW CANAL IN USE TOGETHER, GARVIN'S FALLS.

the right to utilize the entire flow of the Merrimac it was impossible to do so, because the ancient canal originally dug for small boats could not carry the whole river. Furthermore, the composite dam was of uncertain strength. The plan of the Manchester company was, therefore, from the start to build a new dam and dig a canal that would carry all the available water at times of moderate flow. Meantime, as the demands for light and power in Manchester were pressing, an incomplete station was built at the falls and as much generating equipment was installed as the water coming down the old canal would operate. For half a year work has been under way on the new dam and canal, and on the extension of the power house. This work has now reached a stage that gives promise of the early delivery in Manchester of all the power that a 28-ft. fall in the Merrimac will yield.

The construction now under way at Garvin's Falls contemplates an ultimate station capacity of 3,900 kw or 5,200 hp in electric generators. This capacity is to be made up of six three-phase, 60-cycle alternators, each rated at 650 kw and 12,000 volts. Three 39-in. turbine wheels mounted on the same horizontal shaft are direct-connected to each generator and drive it at 180 r.p.m. The rating of each group of three wheels is 1,000 hp. As the station at Garvin's Falls now stands, with 1,300-kw capacity in electric generators, it is the largest electric water power plant in New Hampshire. When the extensions now under way are completed and the station capacity is raised to 3,900 kw, it seems improbable that any electric water power plant in the State will equal it for at least many years to come. This conclusion is supported by the fact that the Merrimac is much the largest river in New Hampshire, and that the fall at Garvin is greater that that at any other point on the river in that State, save the one at Manchester, which is utilized by a great manufacturing corporation located there.

The Merrimac is not a great river, being only 110 miles long from its head, at Franklin, N. H., to its mouth at Newburyport, Mass., neither is its elevation exceptional, for the head waters at Franklin are only 269 ft. above sea level. Nevertheless, this comparatively small river probably turns more spindles than any other stream in the United States or even in the world. This is due to the fact that three of the four largest powers on the river, those at Manchester, Lowell and Lawrence, are mainly devoted to the manufacture of cotton goods. Considering its length, the drainage area of the Merrimac is exceptional, being 4,864 square miles. At Lawrence, 28 miles from the mouth of the river, the drainage area is 4,553 square miles, and the mean annual discharge of water from 1890 to 1897, inclusive, ranged between 4,850 and 9,373 ft. per second. Above

Garvin's Falls, which is 83 miles from the mouth of the Merrimac, the drainage area is 2,400 square miles, and it is estimated that the head of 28 ft. there will yield at least 5,000 hp during nine months of each year. During the great freshet of March 2, 1896, the largest in the history of the river, it is estimated that the discharge at Garvin's Falls rose to 72,000 cu. ft. per second. At Lawrence the fall of the Merrimac is 29 ft., and at Manchester it is 52 ft., and these are the only other two points on the river where the height of the fall at Garvin's is approached.

The old dam at Garvin's Falls is located about 1,240 ft. up stream from the power station, and water formerly came down to the station through the old canal of that length. Between abutments the old dam, built in 1859, and partially rebuilt in 1879, has a length of 454 ft. The old canal is a rough excavation of irregular cross section, and has an overflow wall of timber and stone for a part of its length on the side next to the river. The new dam is being built across the river at a point approximately 500 ft. up stream from the power station, and something more than 700 ft. below the old dam. In length the new dam is about 550 ft. between the abutments and these latter, together with their core walls and the head gate wall, extend up into the banks about 160 ft. on the canal side and 80 ft. on the opposite side of the river, beyond the central portion of the dam. On the right-hand side of the river, at one end of the new dam, the new canal begins and in its course to the power house it

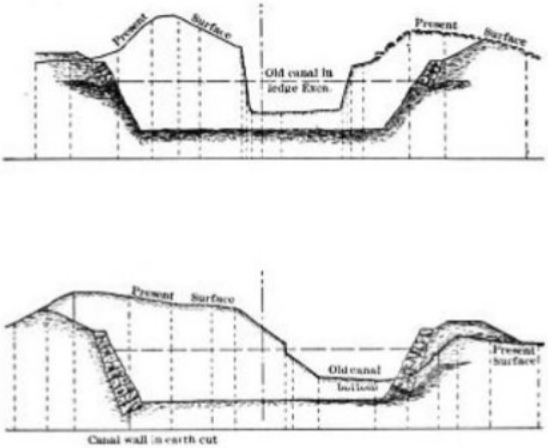

FIG. 3.—CANAL PROFILES.

overlaps substantially the entire site of the lower 500 ft. in the length of the old canal. The new site selected for the dam not only afforded a natural rock foundation with comparatively little excavation, but also shortened the required length of canal by more than 700 ft.

Of the total length of about 550 ft. in the central portion of the dam, 70 ft. at the left-hand end has a crest 2 ft. above that of the remainder in elevation. For its entire length the dam rests on the natural ledge in the bed and banks of the river. In general outline the dam is straight and its height above the bedrock varies from about 10 to as much as 25 ft. between the elevations of heel and crest. A notable feature of the dam is its width up and down stream, which amounts to as much as 31 ft. from heel to toe in the part that is 25 ft. in elevation from heel to crest. The portion of the dam between the abutments is of stone masonry laid in mortar of Portland cement and sand. Ashlar masonry is used on the crest and down-stream face of the dam, and rubble masonry for its up-stream face and core. Of that portion of the dam between the abutments three sections have been completed, one section adjoining each abutment and one about mid stream, and if the weather is favorable it is expected that the entire dam will be completed during the winter. Both of the dam abutments, including the head gate wall at the entrance to the canal on the right-hand bank, are practically finished. The right and left bank abutments are formed of concrete and faced with ashlar masonry, and the head gate walls are built entirely of concrete.

When the new canal is considered, the importance of the change made in the water power development at Garvin's Falls becomes evident. The striking feature of the new canal is its great increase in area of cross-section over that of the old. It is hard to state accurately just what is the cross-section of the old canal, since this varies materially in the course of its length, but it may be put at approximately 264 sq. ft. for at least a part of its course, up to the

FIG. 4.—HEAD GATES, NEW CANAL, GARVIN'S FALLS.

top of its banks. Compared with this, the area of cross-section for the new canal to the top of its banks is 1,260 sq. ft. at the entrance to the forebay. Up to its flow line the canal has a cross-section of 750 sq. ft. before it widens into the forebay. The new canal has been excavated partly in earth and partly in ledge, and some filling has been necessary along its banks. In all cases where the canal wall or any part of it is in earth, this wall is of concrete or stone masonry. Before entering the forebay the canal at its flow line, which corresponds in elevation with the top of the dam in its midstream section, has a width of 74 ft., and this flow line is 13 ft. above the canal floor. In its course of about 500 ft. between the head gates and the forebay the level of the canal floor drops one foot.

The floor of the forebay gradually drops to a level four feet below that of the canal at the point of entry. This gives the water in the forebay, when just up to the level of the top of the dam at its

FIG. 5.—CANAL FROM HEAD GATES, GARVIN'S FALLS.

middle section, a depth of 17 ft. At the river side of the forebay is an overflow wall 90 ft. long with a crest that is 2 ft. above that of the river section of the dam. At the rack the width of the forebay is increased to 134.5 ft., and 80 ft. of this rack length represents the new addition. In vertical height the rack is 20 ft., and its top is 3 ft. above the crest of the river section of the dam. In the forebay wall near the river end of the rack are the waste and flush gates. The entire floor of the forebay was excavated in the ledge of the river bank.

The head wall of the forebay forms also one side of the wheel room at the power station. This station thus sets directly across the lower end of the canal, and is connected with the river by a short tail race. On the top of this head wall of the forebay, which is of

stone masonry and rises to an elevation 8.5 ft. above the crest of the river section of the dam, there is a pent house containing electric motors that operate the gates of the several wheels. When completed the power station will have an outside width including the head forebay wall of 67 ft., and an outside length of 149.75 ft., at the foundation level. Of this total length that part of the station built in 1901 forms 65.5 ft. The wheel room from the outside of the head wall of the forebay to the wall that separates the wheel and generator rooms is 33.5 ft. wide, has less elevation than the remainder of the power station, and is covered by a nearly flat roof. Inside of the generator room the width is 30 ft. and the length about 146 ft. Above the stone foundations the station walls are of brick and the parallel walls on the two longer sides are each 24 in. thick to an elevation of 20 ft. above the floor of the generator room, at which elevation their thickness shrinks to 9 in., giving a shelf 15 in. wide to support the traveling crane. Beneath the generator room there is a stone foundation resting on bedrock and consisting of arches, and this foundation is pierced by seven arched openings, which connect an open space beneath the entire wheel room with the tail race.

The floor of the wheel room is of spruce plank laid on steel I-beams that rest on the head wall of the forebay at one end, and on the arches beneath the generator room at the other end. These I-beams also support the wheel cases, which are hung between them. Seven steel wheel cases pierce the forebay wall and extend into the wheel room. Each of six of these cases is 12 ft. in diameter and contains three 39-in. horizontal turbine wheels. The seventh case is 5 ft. in diameter and contains two turbines of 12 in. diameter each. From

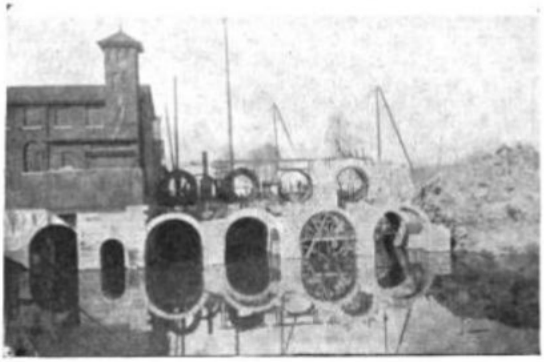

FIG. 6.—NEW FOUNDATIONS FOR ADDITION TO GARVIN'S FALLS POWER STATION.

each wheel case two draft tubes extend down to a level below that of the tail water. From each set of wheels the horizontal shaft extends through a water-tight bearing set in the wall that separates the wheel room from the generator room, and is direct-coupled to that of a generator or exciter. The center of the shaft of each set of main wheels and of their generator is 10.5 ft. below the crest of the dam at its river section, and 17.5 ft. above the ordinary level of the tail water.

In the generator room the concrete floor is supported by the stone arches beneath, and rests in part on I-beams that span the spaces between them. The floor is finished with a layer of Portland cement mortar 2 in. thick. As the floor level in the generator room is 15 ft. below the crest of the dam at its river section, and 5.24 ft. below the level reached by the back water in the great freshet of March 2, 1896, the highest on record, both the floor and the walls were made water-tight up to a level 2 ft. higher than that reached by the back water during the freshet just named. With this construction the power station may continue in operation when high water backs up about its outside walls and in the wheel room to an elevation more than 7 ft. above that of the floor in the generator room. As the entrance to the station, at the end more distant from the river, has an elevation as great as that of the dam crest, and about 10 ft. above the freshet level no water can enter there.

Beneath each of the 650-kw alternators in the generator room there is a pit 12 ft. long, 6 ft. 2 in. wide and 2.5 ft. deep beneath the floor level. Each of these pits is connected by iron pipe with a drain tank set beneath the floor level, and water is removed from this tank by means of a small centrifugal pump driven by a motor. From each or the pits beneath the main generators and also from each of the two exciters, conduits are laid to the switchboard bay. This bay is located about midway on that side of the generator room opposite to the wheel room. Exclusive of the switchboard bay the total width of the generator room is only 30 ft., and of this width the row of generators takes up 17.5 ft., leaving only 12.5 ft. between

FIG. 7.—LAYING FOUNDATIONS FOR ADDITION TO POWER HOUSE.

the outer end of a generator bearing and the wall. The switchboard bay juts out on the tail race side of the generator room with a length of 33 ft. and a depth of 6.5 ft., above the foundations. Inside the switchboard bay measures 7.5 ft. wide and 26 ft. long at the floor level, and the lowest point on the inside of its slanting roof is 16.5 ft. above the floor. The switchboard sets in this bay so that its face is nearly in line with the inside surface of the main wall of the generator room, and this location leaves ample room for access to the rear of the board, which is reached through a door at one end. Beneath the switchboard and running its entire length is a trench in the concrete floor 10 in. wide and 12 in. deep, where the conduits carrying cables from the generators and exciters terminate. In the side wall of the switchboard bay at an elevation above the top of the board a row of slate slabs are set in the brickwork, and these slabs are pierced by circular openings through which the bare conductors pass that transmit the energy of the water power plant to the substation in Manchester, 14 miles away.

As matters stood at Garvin's Falls early in 1903, before construc-

FIG. 8—RACK AND FOUNDATION FOR ADDITION TO GARVIN'S FALLS POWER STATION.

tion on the extension of the power plant was started, it was necessary to discontinue the operation of the station altogether, while the new canal and the foundation for the addition to the station were being built. The 1,300 kw of generator capacity in the incomplete station could be shut down with the least loss during the summer months, and the general contract for the new dam, canal and extension of the power station was accordingly closed on June 5, 1903, with the provision that the new canal, station foundations and the

deepening of the tail race were to be first completed. This plan has been carried out, water was let into the new canal in November of the present year, and the older portion of the power station with its two 650-kw generators is now in regular operation. It remains to complete the new dam and the addition to the station above the foundations, and to remove a portion at least of the old dam of 1859. This old dam and the upper section of the old canal are still in use to divert and deliver water to the new canal. The upper 700 ft. in the length of the old canal brings water down to the head gates of the new canal, and will continue to do so until the new dam is completed. By this use of the old canal it is possible to maintain a dry river bed for work on the new dam, while the new canal is in use. The work of construction can now go on without interfering with the operation of the older part of the power station, and it is expected that the entire development will be completed during the first half of 1904.

The Manchester Traction, Light & Power Company, the owner of the electric light, power and traction systems in that city, owns also the entire water power rights and developments at Garvin's Falls. Hollis French and Allen Hubbard, consulting engineers, of Boston, are the engineers for the Manchester company on all of the work above described, being represented at the work by Mr. George G. Shedd, resident engineer. The general contractors for the work are Holbrook, Cabot and Rollins, and their superintendent at Garvin's Falls is Mr. J. B. Haviland. The other contractors on the plant are, for steel work, the Boston Bridge Works; for the station building, Waymire & Penniman; for the electrical machinery, the General Electric Company; for the switchboard, S. B. Condit, Jr. & Co.; for the water wheels, the Rodney Hunt Machine Company.

Especial thanks are due to Mr. J. Brodie Smith, general manager of the Manchester Traction, Light & Power Company, and to the engineers, Hollis French and Allen Hubbard, for aid in the collection of the above facts.