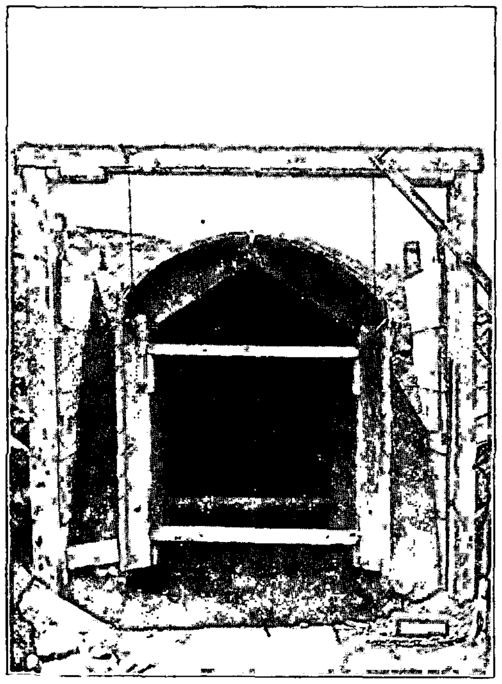
The Water-Supply System of Salt Lake City, Utah.

The water supply of Salt Lake City, Utah, is obtained from several mountain streams through a combination of water rights which are believed to be peculiar to that locality. The city is on a sloping plain close to the westerly base of the foot-hills of a range of mountains that extends nearly north and south, with the Great Salt Lake a few miles to the west. The annual total precipitation in the surrounding region has varied from 21 in. as a maximum for the period from 1874 to 1878 to between 15 and 16 in. for the past 20 years. The rainfall during the summer is especially light, the average for the four months from June 1 to October 1 of each year from 1874 to date having been not more than 3 in. These rainfall conditions, coupled with the fact that the adjacent country is intensely cultivated under irrigation, render exceedingly valuable the rights to divert water from the streams which have their sources in the mountains. The municipal supply has, however, always been obtained from these streams because the water from the latter is particularly pure and cold, while all other available sources are objectionable, from one cause or another, for domestic consumption.



Forms for Big Cottonwood Conduit.

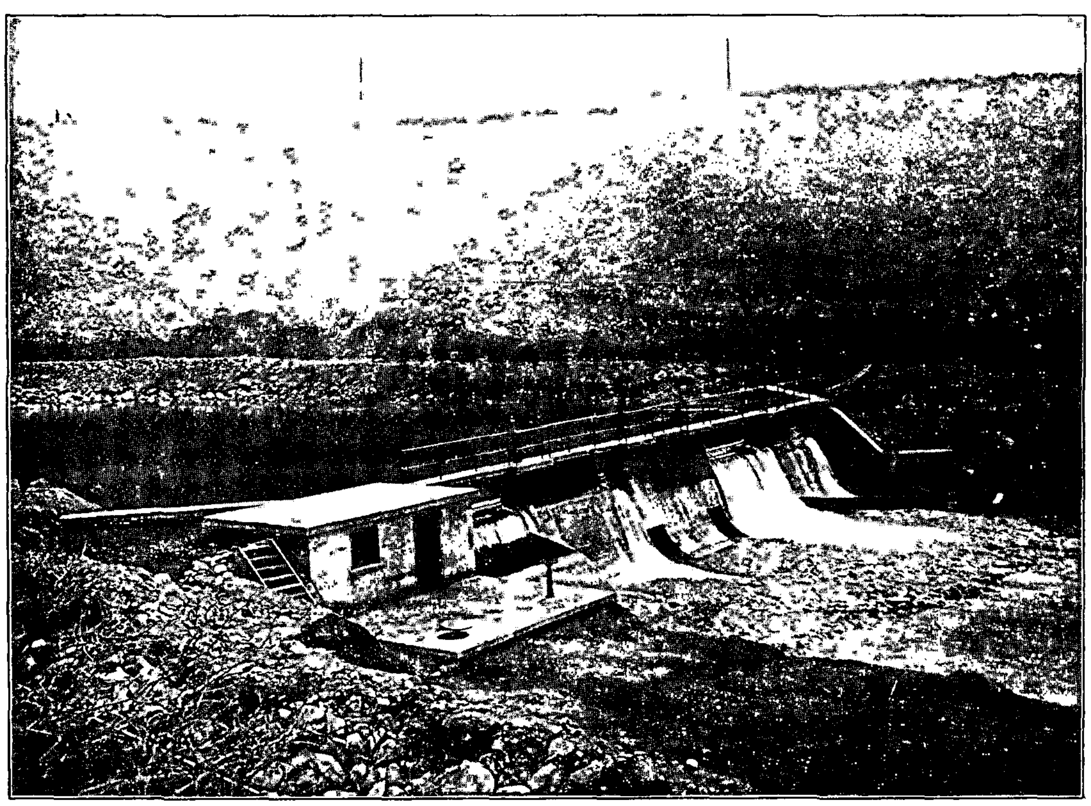
The original mountain water supply was obtained from City Creek and Emigration Creek, two small streams which have their sources in the mountains and flow through the city into the Jordan River. The supply available from these two streams was delivered by gravity to the distribution system of mains by two separate conduits. The quantity available from these two streams long ago became inadequate, so additional supplies had to be obtained. The closest stream of any considerable flow was a creek in Parley's Canyon, which creek extends along what is now the southern boundary of the city. The waters of this creek were fully appropriated, however, for irrigation purposes. Nevertheless, the city obtained rights to a large percentage of the flow by exchanging water from Utah Lake, a broad body of fresh water 25 miles south of the city, for the quantity diverted from the stream. Later, when the supply again became inadequate, this exchange of rights was further extended in order to permit the diversion of water from Big Cottonwood Creek, a stream of considerable size some 10 miles below the city. Plans have been perfected, also, to continue the extension of this exchange for more water from this and other streams, so the city is thus assured of a sufficient supply for many years, while the possibility of constructing storage reservoirs on the watersheds of the different streams will render available all the water necessary for any demands that may be expected.

The conditions involved in the exchange of water rights in a semi-arid region similar to the one surrounding Salt Lake City, where the irrigation of the land has given a very great value to these rights, are particularly acute. The waters from the streams now used chiefly for the municipal supply have been diverted during the past forty years to irrigate an area of about 17,000 acres. The land comprising this area is owned in small tracts of about 15 acres each, and is generally in a high state of cultivation. Most of the area is devoted to the production of fruits, vegetables, sugar beets and alfalfa hay, and with sufficient water for irrigation yields abundantly. The average value of the land and improvements is about $175 per acre, making the whole area worth nearly $3,000,000.

Construction of Conduit.

The water from all of the mountain streams is pure and clear, but its temperature is too low and its flow too variable to best serve the purposes of irrigation. On the other hand, for domestic consumption and municipal uses the water is well suited and is also favorably situated. Incidental to its use for irrigation, the mountain water was also formerly used for culinary and other domestic purposes by all those living on the irrigated land. This incidental use is still continued on the upper portions of the area described, but on the major part of the area lower down flowing wells now furnish water for domestic purposes. The dependable flow from City Creek, Parley's Creek and Big Cottonwood Creek combined is about 50 cu. ft. per second in seasons of low water. At flood stages the flow is perhaps as much as 900 cu. ft. per second. A low flow generally occurs late in the irrigation season with the result that, when depending on the streams, the maturity of a full crop on all the land under irrigation is never realized.

The water from Utah Lake, on the other hand, is turbid and much warmer than the mountain water, which with other conditions render it entirely unsuited for domestic consumption, although quite preferable to the mountain water for irrigation. Furthermore, the lake is at so nearly the same elevation as the city that water cannot be delivered from it to the latter by gravity under sufficient head to preclude the necessity of pumping into the distribution mains. At the same time, the lake is sufficiently above the irrigated areas formerly dependent entirely on the mountain streams that water can be delivered to that area from the lake by gravity. A canal was built from the lake to the city by the latter about 25 years ago, and the city owned sufficient rights in the waters of the lake to divert enough water into this canal to irrigate practically all of the area dependent on the mountain streams. Notwithstanding the fact that all physical conditions were thus favorable to an exchange of rights, the prejudices and other circumstances surrounding the ownership of the rights in the streams made arrangements for such an exchange difficult to consummate. These prejudices and circumstances unfavorable to an exchange of rights have, never



Diverting Dam at Head of Big Cottonwood Conduit.

theless, been overcome sufficiently to obtain all the water from the mountain sources necessary for any demands that may be expected in the near future. By the purchase of rights on the streams and by exchange of lake water the flow of the mountain water can later be rendered almost entirely available for municipal consumption.

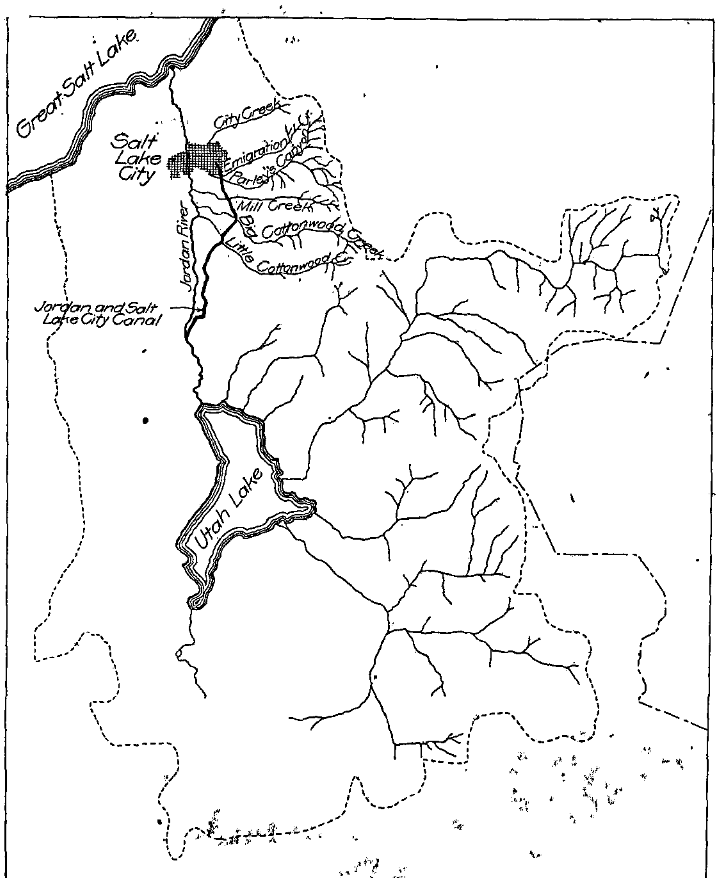
The first water rights to be acquired by the city through the medium of exchange were those of the farmers who originally appropriated water from Parley's Creek for irrigation. The contract under which this exchange was made is dated June 25, 1889, and its general terms are that the city shall divert and use a portion of the flow of the creek in exchange for a substituted supply to be turned into the farmers' ditches through the municipal canal from Utah Lake. The contract provides that the flow of the creek shall be measured twice each irrigation season; that the quantity of flow at the first measurement shall be that which must flow constantly from the municipal canal into the farmers' ditches during the period between the first and second measurements, and that the quantity of flow at the second measurement shall be that which must flow into the ditches from the canal during the remainder of the irrigation season. The farmers thus enjoy the advantage of an undiminished flow throughout the periods succeeding each measurement made, while the flow received by the city from the creek in exchange diminishes daily throughout the same periods. The flow to the city, however, is continuous throughout the year, while the period of flow to the farmers is limited to the irrigation season of about 150 days.

Although this plan of procuring water for municipal purposes is, perhaps, peculiar to Salt Lake City, the situation and controlling circumstances are such as to compel the unusual methods. The price of the land and improvements which would have to be included in the cost of rights to divert water from the intensely irrigated lands are prohibitive. At the same time, the greater portion of the city's supply of water was provided in pursuance of the terms of the contract for the waters of Parley's Creek for 18 years prior to the completion of a conduit to convey water to the city from the Big Cottonwood Creek. During this time, also, the supply has been equally as regular and dependable as from other sources of supply in which the city is absolute owner. Based on this result, the city procured rights to thirty-sixtieths of the flow of the Big Cottonwood Creek in exchange for the lake water. A course to acquire in a similar way the right to use this entire stream as well as to parts, or all of the Little Cottonwood and Mill Creeks, two adjacent streams, is being persistently pursued.

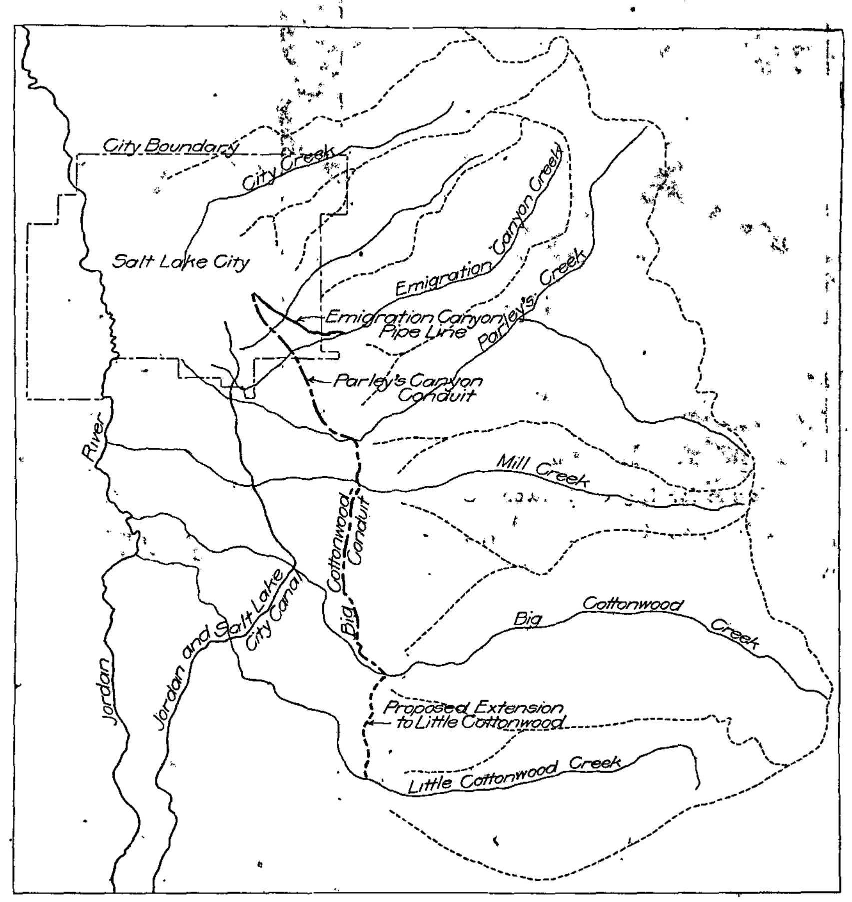
Utah Lake Pumping Station. Utah Lake is a shallow body of water with a maximum width of 12 miles and a maximum length of 23 miles, that is fed by several mountain streams, and also has some connection with underground watercourses. The level of the lake is naturally controlled by the rainfall conditions and varies as much as 5 ft. When at the higher levels, the lake overflows into Jordan River, which carries this overflow into the Great Salt Lake, some 30 miles distant; at periods of low water in the lake, however, this stream is naturally dry. The flow in the river has for many years been diverted for irrigation purposes, most of the land thus supplied being formerly cultivated during years of more favorable rainfall. In order to overcome the deficiency of flow in the river during dry years a pumping station was installed at the head of the Jordan River in 1902. The equipment of this station is arranged to lift the water from the lake and discharge it into the river when the lake level is too low to cause such a flow naturally. The flow of the river is diverted into five different irrigation canals below the station, one of which is the one built by Salt Lake City.

The pumping station is owned by five irrigation companies, four of which are made up of the farmers along the canals and the fifth is Salt Lake City; the latter also owns a one-fifth interest in one of the private companies. The station contains seven 40-in. Byron-Jackson electrically-driven centrifugal pumps, with a normal capacity of 100 cu. ft. per second each, thus making the output of the station over 450,000,000 gal. per 24 hr., which is believed to be the largest of any water-supply pumping station thus far built. The first four pumps installed are owned jointly by the five companies, while four of the companies own a one-quarter interest in two of the other pumps, and the seventh is owned by three of the companies. The city, therefore, is interested in all seven of the pumps.

The first five pumps installed were in a row in the concrete substructure of a 103 x 34.5-ft. building. Three pumps were placed on a floor 5.5 ft. below a level in the lake established by compromise, which level has been exceeded by as much as 2.05 ft. by the stage of water in the lake. Each pump is of the double-suction type, and operates against a head of from nothing to a maximum of 5 ft. The inlet connections on the lake side and the discharge pipes on the river side are each provided with a flap valve to prevent back-water from either direction from flowing through the pumps. Each of these five original pumps is belt-driven by a 100-h.p., 440-volt, Type K Westinghouse alternating-current continuous-speed motor.



Map of Vicinity of Salt Lake City.

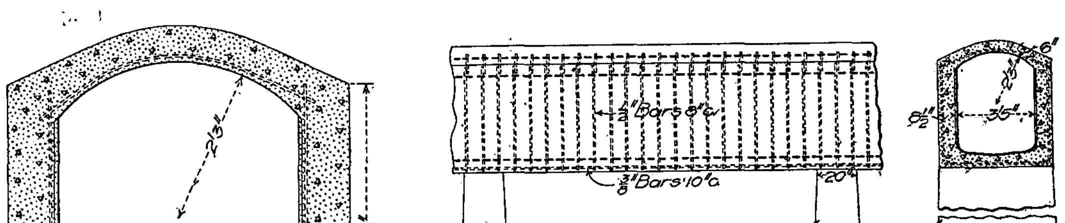


Sources of Water Supply for Salt Lake City.

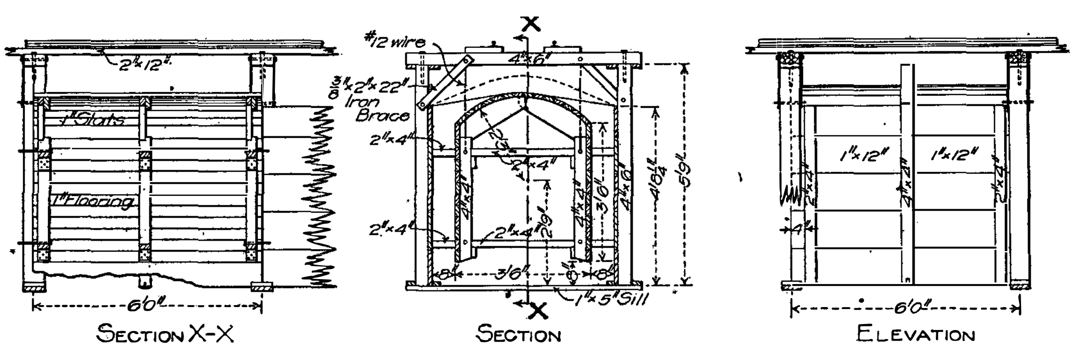
The two additional pumps have only recently been installed and are of the latest improved pattern 40-in. Byron-Jackson centrifugal type. These pumps are in a 49.5 x 25-ft. addition to the original building, which addition, like the original building, has a heavy concrete substructure on a pile foundation. Each of the pumps is geared through a shaft carrying a friction clutch to a 150-h.p. 440-volt alternating-current continuous-speed Fairbanks, Morse & Co. motor. These motors are at the same level as the pumps, the pit being made water-tight. The shaft of one of these new pumps is also arranged with a second friction clutch so it can be driven by a 130-h.p. four-cylinder tandem-compound two-cycle gasoline engine, built by the Jacobson Gas Engine Co. This engine was installed by the city in order that the one pump could be operated in case the supply of electrical power is interrupted. Sufficient water can thus be delivered to the river at all times to supply the amount necessary to exchange for the quantity diverted from the mountain streams. Since the flow in the river is sufficient, however, to supply all of the canals during years when the rainfall is above the normal, the station is frequently idle for considerable periods, but is always necessarily maintained in readiness to operate.

The electrical power used to operate the station is obtained from a hydro-electrical development at the foot of the mountains, 19 miles away. Current is transmitted from this development to the station at 5,000 volts over a pole line, and is stepped down to 440 volts by a bank of five 175-kw. oil-cooled transformers in a row of separate brick cells outside the station building. The operation of the motors is controlled from a switchboard in a separate room between the old and the new parts of the station building.

Water is diverted from the Jordan River into the municipal canal through headworks in a dam about 12.3 miles below the pumping station. This canal is 24.5 miles in length, extending down the right side of the river to the city. It was built to deliver the lake water directly to the city and as such has served the purpose well; but its capacity is not great enough to supply lake water in exchange for mountain water from the Big Cottonwood Creek and other similar sources. The location of this canal is also such that it cannot be made to deliver exchange water to all the land from which the mountain water can be procured by substituting lake water. The East Jordan canal, another irrigation canal, is located, however, on the same side of the river and the city owns a one-fifth interest in this canal, which has a right to 170 cu. ft. per second from the lake. This canal is located on the highest contour along which it is possible to convey water from Utah Lake by gravity, and throughout its entire length of 18.5 miles is parallel with, and 55 ft. in elevation above the municipal canal. Plans have been consummated whereby the first 19 miles of the municipal canal, extending to the crossing of Big Cottonwood Creek, may therefore be abandoned by enlarging and extending the East Jordan canal to carry the entire city exchange supply in addition to the supply for the private canal. An extension from Little Cottonwood Creek to Big Cottonwood Creek capable of carrying the city's supply would then discharge into the latter creek and from it be recovered into the farmers' ditches and into the remainder of the city canal.



Details of Big Cottonwood Conduit.



Details of Forms for Big Cottonwood Conduit.

Conduit System. The oldest conduit which delivers water to the distribution system is a 12-in. wood-stave pipe line 1.5 miles long, leading to that system from City Creek, northeast of the city. The surplus carried by this conduit is delivered to three storage tanks, with a combined capacity of 325,000 gal.; these tanks act as pressure and supply regulators. The second oldest conduit is a 12-in. Kalamined pipe line, about 3⅛ miles long, which extends from an intake on Emigration Creek to a 5,000,000-gal. distribution reservoir on the hills to the east of the central part of the city.

The water of Parley's Creek is delivered into the city by a 36-in. concrete conduit, 5.1 miles in length, which extends from a diverting dam on the creek to the same 5,000,000-gal. reservoir into which the Emigration Creek conduit delivers. A 1,690,000-gal. reservoir is placed in the canyon of Parley's Creek, at the diverting dam, in order to provide for daily fluctuations in demand and for sedimentation. This reservoir was created by a masonry dam across a narrow part of the canyon and has recently been lined with concrete. A wood-stave by-pass has also been built around the reservoir, in order that the latter may be cut out of service if desired.

The conduit which has recently been built to deliver the water from Big Cottonwood Creek to the city has a total length of 38,167 ft., or 7.23 miles, extending from a diverting dam and headworks near the mouth of the canyon of that creek to a connection with the conduit which extends from the reservoir in Parley's Creek canyon to the city. This new conduit is of reinforced concrete and crosses Mill Creek, arrangements having been made to divert the waters of that stream into it. Plans have also been prepared to extend the conduit 4.5 miles beyond the present upper end to the Little Cottonwood Creek. The conduit, as built, has a capacity for carrying 39,000,000 gal. of water per 24 hr., which is probably as much water as can be obtained from the three streams.

The diverting dam and headworks of this conduit on the Big Cottonwood Creek consist of a gravity-section overflow concrete dam, with a screen and gate chamber in one end which connects with the conduit. The dam is 11 ft. high above the base and 94.5 ft. long at the crest. In order to prevent underflow a cut-off wall 4 ft. wide was extended 22 ft. below the footing, flush with the up-stream side of the dam, the latter being on a deposit of gravel and boulders mixed with clay. A 12-in. apron of concrete was also extended down-stream 6 ft. 4 in. to avoid scour in the bed of the stream. The overflow crest of the dam is controlled by two Cippoletti adjustable steel weirs, which permit the amount of opening to be varied and the flow of the stream to be measured. The flow over one half of the dam may be diverted into the screen chamber of the conduit through one weir opening, or that weir may be moved so no water reaches the chamber. Two 3.5 x 3.5-ft. openings through the dam are placed near the bottom of the latter, between the two weirs, and are each provided with a sluice gate so the reservoir above the dam may be flushed out. These two gates and the weirs are controlled from a concrete footway carried longitudinally over the crest of the dam by two I-beams.

The designs and construction of the conduit were described briefly in The Engineering Record of July 13, 1907. The conduit follows a hydraulic gradient along the side of the foot hills from the diverting dam to Parley's Canyon. Two different sections were used for the conduit in this distance, the one first adopted being rectangular, while the second has an arched instead of a flat roof, both sections being 3.5 ft. wide. A length of only about 1,050 ft. of the rectangular section, which is 4 ft. high, with the invert depressed 2 in. at the center by making it 8 in. thick at the sides and 6 in. thick at the center, was built. The side walls of this section are 6 in. thick, and the flat roof from 4 to 6 in. thick, according to the depth of cut in which the conduit was built. In the arched section the invert is the same as in the section which it superseded, except that the corners between the invert and side walls were rounded to prevent lodgement of impurities. The thickness of the side walls was also increased to 8 in. The arch roof was increased to a thickness of 6 in. at the center and given a rise of 10.3 in., the skewbacks being made 10.3 in. deep. The sides and invert are plastered with a ½-in. coat of cement mortar.

The side walls are each reinforced under normal conditions with a row of ⅜-in. bars placed ½ in. from the inner face of the wall and spaced 6 to 8 in. apart. The arch is reinforced with a row of ⅜-in. bars, spaced the same as those in the side walls. In various places where the conduit crosses small watercourses, or depressions below the hydraulic grade, it is carried on concrete piers above the level of the ground. In such cases ½-in. rods, 8 in. apart on centers, were used in the side walls and arch, and the invert contains ⅜-in. longitudinal bars placed 10 in. apart on centers.

The concrete piers on which the conduit is carried over the small watercourses and depressions have a cross section at the top 20 in. wide and of the same length as the width of the conduit, the sides of the piers being built on a batter of one-half inch to one foot. These piers are on a footing course 12 in. thick and 8 in. wider on all sides than the base of the pier. They are spaced 15 ft. apart on centers and were built in advance of the conduit, in order to form a true joint between them and the bottom of the latter, thus allowing for movements due to temperature changes. Since the conduit is covered with at least 2 ft. of soil in all exposed places and the water which it carries varies only slightly in temperature, any such movement is slight.

The conduit is laid on a 0.12 per cent. grade to Mill Creek and thence on a 0.15 per cent. grade to within 800 ft. of the connection to the Parley's Creek conduit. The carrying capacity is 32,000,000 and 39,000,000 gal. per 24 hr., respectively, for the two different rates of grade, thus providing for the admission of water from Mill Creek. In the last 800 ft. the conduit drops 180 ft. over the side of a steep hill by means of a series of short sections with varying grades. Three blow-off connections with mud drums are provided at convenient points along the conduit to allow the latter to be drained for cleaning or in an emergency.

A wagon road had to be built along the entire line of the conduit so construction materials could be delivered, as the location is for the most part well up on the steep sides of the foot hills isolated from any means of transportation. The concrete was made of Utah Portland cement, sand and gravel obtained from pits adjacent to the conduit in the proportions of 1:2.5:4.

The concrete was made in a Smith concrete mixer set up over the site or immediately at one side of the conduit, at intervals of about 1,000 ft., and at points where materials could be readily supplied to it. The details of the concrete forms are shown in an accompanying illustration. The concrete was delivered from the mixer to place in four-wheel ½-yd. steel dump cars running on a 24-in. gauge track laid on planks carried by 4 x 6-in. caps on 4 x 6-in. posts of the forms.

The forms were built so the concrete in the invert, side walls and arch could be deposited simultaneously. The wall forms were built in sections 6 ft. long and were hung by wires from the 4 x 6-in. caps carrying the car track.

The ribs of the arch form seated on vertical posts of the inner forms of the walls, so the core of the form could be swung and blocked in position readily. Then, when the concrete had set, the side and arch forms could be easily removed by clipping the wires supporting the sides.

The distribution mains to which the Parley's Creek conduit delivers had an actual capacity of only 7,500,000 gal., and as the flow in City Creek is decreased at times to less than 3,000,000 gal. per day, the total possible supply that could be delivered was less than 10,000,000 gal. In order, therefore, to make available for distribution the 20,000,000 gal. of water capable of being delivered at the end of Parley's Creek conduit after the completion of the new Cottonwood Creek conduit, a new main, 2.08 miles long, consisting of 0.75 miles of 36-in. cast-iron pipe and 1 1/3 miles of 30-in. cast-iron pipe, has recently been laid from a point on the Parley's Creek conduit into the city. The upper end of this main is 447 ft. above the center of the city, so a pair of 24-in. pressure regulator valves were placed on it at a point where the pressure rises above desirable operating conditions. These regulators are between two Y-connections and are in a concrete gate chamber, 10 x 18.5 ft. in plan. A hand-operated gate valve is placed on each side of both regulators and an air valve is provided on the down-hill side of the pair. The sides of the chamber are carried 10.25 ft. above the ground level on the down-hill side and are covered with a flat concrete roof reinforced with I-beams. A two-wheel traveling crane is suspended over the longitudinal center line of the house on a 4-in. gauge track carried by a pair of 10-in. 35-lb. channels hung from the I-beams of the roof.

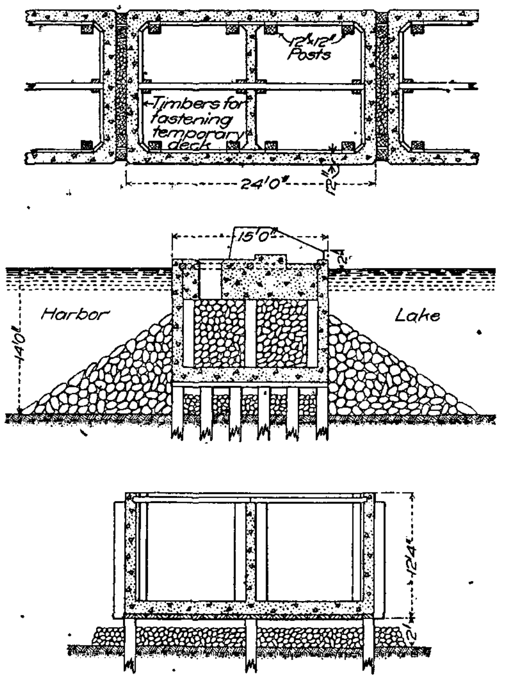
The water-works system of Salt Lake City is under the supervision of Mr. Louis C. Kelsey, city engineer. Mr. Geo. O. Chaney is principal assistant engineer; Mr. A. F. Doremus is assistant engineer in charge of the exchange of water rights and Mr. L. L. Parke is assistant engineer of the water-works division.

A PIPE COIL RADIATOR without threads has been devised for use in temporary heating installations. It is made up with fittings, reamed tapering, into which the pipe ends, turned to corresponding tapers, are snugly driven. The coils are found to be steam-tight under low pressures and can be mounted or taken down by inexperienced labor.

A Novel Breakwater for Algoma Harbor, Wis.

The existing harbor at Algoma, Wis., is in the mouth of Wolf (or Ahnapee) River, connected with Lake Michigan by a channel protected in the usual manner by wooden piers. With the increasing draft of vessels the old harbor has become useless, cannot be deepened economically by reason of the bed of the river being rock, and if deepened would be unduly effected by wave action.

A small outer harbor is to be secured by the construction of about 928 lin. ft. of pile or plank



Caissons for Algoma Breakwater.

crib pier and about 500 lin. ft. of breakwater made of reinforced concrete caissons. About 650 ft. of old pier will be removed and the harbor will be dredged to a depth of 16 feet below datum. The cost of the work, including repairs to the north pier, will be about $144,000.

The principal feature of the work from the standpoint of engineering interest is the breakwater, which will consist of reinforced concrete caissons, resting on pile foundations, filled with meagre concrete and riprap stone, protected on both sides by riprap and capped with a superstructure of solid concrete, as shown on the accompanying diagrams. The foundation piles are to be supplied by the government; they will be driven to a minimum depth of 30 ft. below datum or until a suitable resistance is developed and then cut off below water so as to secure a horizontal bearing for the bottom of the caissons at a depth of 11 ft. 4 in. below datum. After the pile tops have been cut off, the space between the piles and up to within 9 in. of the pile tops will be filled with small stone, care being taken that no stone shall project above the piles so as to prevent a caisson from coming to full bearing upon all its foundation piles. Before sinking the caissons, the tops of the piles will be brought to within ¼ in. of the proper grade by recutting the piles or by the use of shims.

A cast iron bearing plate, with upper and lower surface suitably roughened to sink into the pile below and the plank above when under pressure, will then be placed on top of each pile. This bearing plate will at the same time tend to equalize the bearing upon the piles and to increase friction between the piles and the caissons above. The caissons will then be sunk and adjusted in their proper positions.

Each caisson will be 24 ft. long, 15 ft. wide and 12 ft. 4 in. high, rectangular in horizontal and vertical sections, with one transverse wall across its middle. The outside walls will be 12 in. thick, the transverse wall 10 in. thick, and the bottom 16 in. thick. The walls and bottom of each caisson will be suitably reinforced with steel bars as indicated on the drawings. It is proposed to build these caissons on shore at a site where they can be conveniently launched to be towed out to the site of the breakwater. The bottom of each caisson will be laid on a timber floor 4 in. thick through which 8-in. wire spikes have been driven to secure a firm bond between the concrete and the wood. Bolts will be embedded in the caisson concrete for convenience in handling them and short pieces of iron pipe will be embedded in the walls for the admission of water to facilitate sinking, but all bolts and pipes projecting beyond the exposed faces of the concrete will be cut off flush eventually.

The caissons are to be moulded in forms made with special care to secure smooth surfaces and, so far as possible, waterproof concrete. The concrete will be a 1:2:4 mixture of Portland cement, sand and broken stone.

A temporary timber decking will be used during the launching and towing of the caissons, and, when necessary, there will be a temporary waterproofing of their exterior surfaces by an inexpensive method.

The permanent filling for the caissons will be riprap stone surmounted by a 4-ft. layer of meagre concrete. Before the riprap filling is placed timber posts long enough to extend up to the level of the top of the riprap will be placed in each caisson as indicated on the drawing. The surface of the riprap filling will be covered with a layer of burlap on which will be deposited the concrete filling. Where the concrete filling is not covered by the superstructure a 3½-in. course below the level of the finished surface will consist of a special finishing concrete made with small stones. A circular man-hole 2 ft. in diameter with a reinforced concrete cover will be moulded in the concrete filling of each compartment of each caisson. The space between the ends of adjacent caissons will be filled with small stones to a height of 1 ft. below the top of the caissons.

The concrete superstructure will be built of 1:3:5 concrete laid in 25-ft. sections with joints between adjacent caissons. The upper surface of the superstructure will be 4 ft. above datum at the center. Alternate isolated sections of superstructure will be moulded first, each section having suitable anchor bolts in each end to secure a firm bond with the intermediate sections to be laid later. A single thickness of tarred paper will extend entirely through each joint in the superstructure, thus forming distinct vertical joints between adjacent sections.

The improvements at Algoma Harbor have been designed and will be executed under the direction of Major W. V. Judson, Corps of Engineers, U. S. A., in charge of river and harbor improvements on the western shore of Lake Michigan, with offices at Milwaukee, Wis. To protect the interest of the United States, Major Judson patented the floatable reinforced concrete caisson in 1901. Docks and breakwaters have recently been built abroad on this system, but its first use in this country will be at Algoma. It is perhaps needless to say that Major Judson has donated to the United States the right to use his patent.

THE QUARTZ LAMP is the latest electrical lighting apparatus. It is a mercury-vapor lamp with a quartz tube in a glass globe, and resembles an arc lamp in general appearance. It is to be used as a single lamp at 220 volts, and has a rating of 3,000 hefner candles, consuming 0.25 watt per hefner candle-power. Its life is given at 1,000 hours, and an advantage claimed for it is that it is unnecessary to replace any electrodes.