SUBJECT TO REVISION

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CONSTRUCTION OF INTAKES AT THE MILLS OF THE CHAMPION AND TRIMOUNTAIN MINING COMPANIES.

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In 1900 the Baltic, Trimountain and Champion Companies, now subsidiaries of the Copper Range Consolidated Company, found it necessary to procure 20,000,000 gallons of water per day for each of the three mills they had planned to erect on the shore of Lake Superior. The Baltic, with the Atlantic Mining Company, impounded the water of the Salmon Trout river with a steel gravity dam and thereby secured an ideal water supply. The Trimountain and Champion were forced to draw upon Lake Superior for their supply. On the west line of Township 55 N, Range 35 W, they found two mill sites where one intake might serve both. Soundings disclosed a sandstone bottom, ideal for anchoring a crib and pipe. It was free from sand or boulders and inclined about 20 inches per hundred feet.

A timber crib was designed, 56 feet by 42 feet, with two wells and two intake pipes, one for each mill. Shortly afterwards Champion selected a site three-fourths of a mile further west and planned to secure water through a tunnel. Trimountain decided to stick to the pipe and intake crib partly because the sandstone bottom was criss-cross with fissures 1½ to 8 inches wide, with a soft white filling into some of which we drove a steel bar six feet. Consequently it was possible that a tunnel might open enough fissures to make it necessary to put in an air lock and work under air pressure or to abandon it entirely, and put in a pipe.

Another reason was the need of time. It was expected one-half the mill might be finished in a year. A tunnel 1,400 feet long, shore shaft and lake intake might take two years to complete, with a possibility of the intake being further delayed by winter. We believed a crib and 1,400 feet intake pipe, including a trench on the shore end 400 feet long, could be finished in four months, the costs of which should not exceed those of a tunnel. We also believed the pipe could be extended when the tailings encroached upon the inlet.

Trimountain started this work in June 1901, blasting the trench on company account and contracting for the pipe and crib The contractors did well but the trenching suffered not only from storms, which were expected, the shore being exposed from all sides but the south, but from inability to clean out the trench after blasting. The drill platform was suspended from two wire cables fastened to timber supports in the lake. At each setting of the platform three holes were drilled on each side, pointing toward each other, and two vertical on the center line. This covered 12 feet of the trench. Single-bit jump drills were used inside a 2½ inch pipe, three men to a drill. When the drill was withdrawn the hole was charged through the same pipe and the battery firing connection was made. The spuds or legs of the platform were then raised, the position on the cable was marked and the platform was hauled shoreward before the round was blasted.

Two settings a day were drilled, covering 24 feet of the trench. The entire length was blasted before we began clearing out the trench. For cleaning away the blasted rock a five-pronged scraper made of rails was rigged to the wire cable that carried the drilling platform, and was manipulated with an engine. The blasting had looked well done but we could remove only three feet of broken rock from the trench. It was redrilled many times, but only a little rock could be removed after each blasting.

The crib was placed and, by the aid of a diver, 700 feet of pipe laid and partly secured by the middle of September. Another diver was engaged to anchor the pipe already laid. It was then thought possible to finish before winter. On September 17 a violent storm wrecked the 10 by 10-inch legs of our wire cable support and the cables disappeared in the water. After three days the weather moderated, though still rough. Of the 700 feet of pipe laid from the crib toward the shore, the divers found only 300 feet in place. This was then securely fastened and the job was stopped for the winter.

The following May work was resumed with two divers and two crews. It was evident the job was bigger than at first anticipated. The delivery of mill machinery was much delayed, but it still looked as if the mill would be ready before the intake. The damage by the storm taught us to secure the pipe better, and we bedded it in for half its circumference with concrete put in place in burlap bags.

In September the pipe was connected with the shore end behind a coffer dam. We then learned why the trench was so difficult to clean out. The crevices caused by the blasting were filled with a clay cement which was the result of the force of the blast turning some of the sandstone into clay, this clay cementing the broken rock in place. The sandstone underwent some change when exposed to the weather, turning into a clay that made a good cement.

Early in November, 1902, the mill commenced operations. The intake included 1,400 feet of rivetted pipe made of ¼-inch steel plate, in sections each 25 feet long connected with steel flanges formed from ⅜-inch steel plate. On the shore end 400 feet lying in a trench was covered with sand and broken stone. The rest lay on the natural rock bottom. For anchorage 240 holes were drilled, two at each flange and two more sets or pairs along each section. These were close to the pipe. Each hole was fitted with a 1¼-inch eye bolt and fastenings were made as shown at A, plate 1. Concrete in sacks was placed the whole length of the pipe, also shown at A, plate 1. The top of the pipe was left bare. The crib in place had cost $11,972.81. The pipe in place had cost $41,005.55.

In the winter of 1902-1903 the ice dented the pipe, and in the spring the exposed part was covered with concrete put in place in sacks. This required 34,452 bags and cost $11,064.74. The intake was then considered finished and had cost as follows:

Labor	$15,546.51
Divers	9,892.50
Consulting engineer	500.00
Supplies	16,750.68
Pipe, 1,900 feet of 40-inch	8,380.60
Crib in place	11,972.81
Total	$64,043.10

In 1905 it was necessary to repair and reballast the crib. The ballast was gone from the inside, the riprapping from the outside, and the bottom timbers had their corners scoured off. The crib was reballasted with mine rock at a cost of $821.43.

Trouble then began because of tailings from the mill, wood chips and bark finding their way into the well and the pump after storms, cutting out the pump valves and stopping up pipes in the mill. We believed this resulted from leaks in the pipe but an examination disclosed no holes, although the ice had worn the concrete from the pipe for over 200 feet. Because of the murky water all the inspections made by the diver were in almost total darkness and he worked by the sense of touch alone, crawling along both sides of the pipe, feeling with both hands for something wrong.

In 1907 these troubles became so acute that another examination was made. Fortunately the water was clearer and the pipe could be seen from the surface. The diver reported one-third of the covering gone, the pipe flattened down to the ridges of concrete which remained on each side, the rivets in some of the girt seams and in some longitudinal seams sheared, and the pipe split open in three places, one ten feet long and opened three inches.

We covered 356 feet of the damaged pipe with concrete, reinforced with old hoisting cable, using a movable caisson to put it in. The caisson was 18 feet long, 10 feet wide and 8 feet high. The air lock for men was built of a piece of intake pipe. The locks for concrete were 10-inch pipe. The lifting tanks were two sections of intake pipe. Ten working days were required to cover 356 feet, but the caisson was in the water from September 15th to October 8th, stormy weather delaying the work. Work was done during the day, using mill labor. We were able to take care of the regular stamp mill work at night. At the long split in the pipe short pieces of railroad steel were laid across the pipe, burlap was put over the split and the whole concreted over. The mill was shut down for six hours after the concrete was placed there. The caisson work, costing $5,988.97, went smoothly but results were indifferent for reasons noted later. Two Rand three-drill compressors furnished air, and fire hose conducted it to the caisson.

Most of the water pumped must have been sucked in through this big split and the pipe beyond it nearly filled with sand, because on starting the pump six hours after finishing the repair to the split the water was lowered very much for a little while and then came back to its normal level. It was then learned that our cementing job on the split had been partly spoiled that night, the cement having been sucked out of the concrete for six inches above and clear out to the side, leaving the top in good shape. Consequently the sand leaked in the same as before. Two years later we pulled a hose out in the pipe from the shore end and pumped in some air, thus locating the leak by the bubbles.

In 1908 it was found the ballast was again out of the crib and some of the timbers on three walls were gone, on one wall the gap being 14 feet high. These gaps were closed by a diver with 2-inch plank. The crib was ballasted with 200 yards of concrete poured into the compartments through tubes in the roof. The tubes were kept full and withdrawn as the pile came up. This concrete work cost $1,411.01, or about $7.00 per yard. The rising and falling of the water in the crib washed most of the cement out of the mixture. Although the concrete on top got fairly hard the water could be seen sluicing back and forth through it. The next year the crib was again empty.

In 1910 it was hard to get enough water through the pipe. The diver crawled in from the crib end for 285 feet and found the pipe flattened. He then crawled in from the shore end 825 feet, the limit of his air hose, and found the pipe in good shape. A parachute, attached to a suspender cord, was sucked through the pipe while the pump was in operation. With the suspender cord a ¾-inch rope was pulled through. With the rope a skeleton-shaped frame 18 inches in diameter was pulled through from the crib with another rope attached to pull it back. At 291 feet the frame stuck a little but was pulled 35 feet further where it was obstructed. It was withdrawn and a 15-inch frame substituted, but could go only a little further. Then a 14-inch frame was tried. It was tight about the same place the 15-inch frame stuck, but it was pulled through into the pump well. The 18-inch frame was now pulled out from the shore end until it stuck, showing only 155 feet of the total 1,400 feet was damaged, and that all the damage, from the ice, occurred in 15 to 16 feet of water. With this information the tracing shown on Plate 2 was made.

In 1911 we replaced the 155 feet of damaged pipe with good pipe. To remove the concrete placed with the caisson and reinforced with hoisting cable the diver blasted the concrete until some of the cable was exposed. A hook was inserted, with a strong wire rope attached to a powerful winch, which removed the large pieces. The smaller ones were hoisted in a bucket. The pipe was cut in two by blasting with 88 per cent dynamite, and a section removed. The accumulated sand was loosened with a hose and the pump sucked it into the well. A new length of pipe was put in and covered with concrete lowered into place with a self-dumping bucket holding 8 cubic feet. Two other sections were then removed and the rest of the dented pipe was sprung back nearly to its original diameter with a 90-ton hydraulic jack actuated from the scow above. Two new sections were then put in place of the removed ones and the whole covered with concrete. This work cost $2,388.45.

On November, 28, 1911, a violent storm broke the crib away and drifted it a mile west, landing it at the Freda Park. The bottom of the crib and some ballast was left, and fortunately the pipe was not disturbed. The loss of the crib caused no worry, as it had been a constant disturbance. Before the crib was lost it had been decided to abandon the pipe and drive a tunnel with the equipment then in use extending the Champion mill tunnel.

Trimountain's total expenditures on its pipe and crib were as follows:

Original, including 1903	$64,043.10
Filling crib with rock, 1905	821.43
Placing concrete with caisson, 1907	5,988.97
Filling crib with concrete, 1908	1,411.01
Replacing damaged pipe, 1911	2,388.45
Total	$74,652.96

Ground was broken for Trimountain's tunnel intake about December 1, 1911. A shaft was sunk 100 feet below the collar or 74 feet below lake level. A pump station was cut and pumps placed at the bottom. Drifting commenced February 13. Work was in 8 hour shifts. Two drilling machines of butterfly valve type worked simultaneously, two men to a machine; also two trammers to a shift. After blasting the miners and trammers of the next shift cleared away enough to rig up. The bar was set horizontally. The miners drilled upper holes while the trammers mucked the rock. Each shift squared and left the rock for the next shift to muck.

The first 1,000 feet was dry. Then the tunnel began making water, the flow increasing to 600 gallons per minute at 1,500 feet where the face became dry. Water was struck at 1,600 feet and reached a maximum flow of 800 gallons per minute. At 1,770 the face became dry again and remained so until the end of the tunnel was reached, 1,970 feet from the shaft. Aside from the wet spots the work presented no extraordinary difficulties. The work progressed as follows: —December 1 to February 12—Equipment installed and shaft sunk 100 feet.

February 13 to 29, drifted	203 feet
March, drifted	394 feet
April, drifted	378 feet
May, drifted	262 feet
June, drifted	312 feet
July, drifted	280 feet
August 1 to 15, drifted	141 feet
Total	1,970 feet

The inlet which is now under construction at the end of the tunnel where there is 17 feet of rock overhead, will consist of a raise from the tunnel level to the lake bottom. Above this is a concrete collar already in place with an inner diameter of 7 feet and an outer diameter of 20 feet, 8 feet high, covered with a steel grating which rests upon a cast iron ring, with a machine-finished face, bedded in concrete. The collar is placed on the rocky bottom, which here is bare of sand and boulders, and is anchored to the rock with six 1½ inch eyebolts. A pilot hole was drilled in the center of the collar area to a depth of 21 feet and into this an iron bar was cemented. A timber covering strong enough to keep out the water if necessary, when the raise from below holed through, was placed in the position to be occupied later by the grating.

The 21 foot bar driven down from the collar above is being used as a center guide in raising. The raise is 7 feet in diameter, the same as the collar. It is to be brought within 5 feet of the top and holes 14 inches apart will then be drilled around the circumference. These will be driven through to the lake bottom and plugged, the timber covering preventing an inrush of water. Then holes for the center blast will be drilled and the tunnel cleaned up ready for the final blast. The air pipe will be left in the tunnel, just as it had been left in the Champion tunnel, so that air could be forced in to free the screen of anchor ice.

When the center-cut holes are blasted, the dirt will fall in the sump provided for it. After the tunnel fills with water a diver will clean up the inlet hole from the top, blasting the holes that had been drilled on 14-inch centers from below.

The costs of labor and supplies for Trimountain's intake to date with amount estimated to finish the work added, are as follows:

	Labor.	Supplies.	Total.
Surface equipment	$ 713.24	$ 336.86	$ 1,050.10
Shaft sinking	3,816.07	1,807.78	5,623.85
Shaft timbering	456.82	184.96	641.78
Shaft concrete	489.85	235.10	724.95
Tunnel drifting	17,062.12	4,719.12	21,781.24
Tunnel timbering	1,440.20	383.10	1,823.30
Pumping	1,256.37	2,295.55	3,551.92
Intake	862.96	321.80	1,184.76
Channel to pump house	1,083.99	1,014.08	2,098.07
Grand totals	$27,181.62	$11,298.35	$38,479.97

The water supply at the Champion Mill is through a tunnel intake, the construction of which has been very ably described in a paper presented to this Institute in August, 1903, Vol. IX, p. 127, by Mr. F. W. O'Neil. No trouble of note occurred until the winter of 1905, when the supply was shut off almost entirely for thirty hours. We thought fine sand and chips had collected in the bottom of the shore shaft and closed up the tunnel portal. Soundings showed a deposit there, but we had inadequate means to clean it out. An iron two and one-half inches square by ten feet long with prongs, was attached to a rope and plunged repeatedly into the accumulation, the pump keeping the water in the well as low as the suction pipes would permit. Finally the tunnel contributed its usual flow of water. Later an orange peel bucket removed the accumulation, but the amount did not seem enough to have stopped the flow. We suspected that during the agitation some of it had been sucked by the pump into the mill circulation. Several stops occurred that winter of two hours and longer. During the summer there was no trouble but each succeeding fall and winter brought a little more sand and wood chips to the shaft, increasing as the waste sands encroached on the outer inlet. It was finally observed that the water in the well was lower while the pump was in operation than formerly.

In 1908 we operated a clam-shell bucket every Monday morning, the cost being charged to operating and not to the tunnel. In 1909 a diver inspected the outer inlet. The tailings from the mill had filled in as high as the concrete collar around it, which had been built up four feet above the lake bottom. The screen was removed from the recess in the cast iron rig over the inlet, a steel shell of ¼-inch plate, 9 feet in diameter and four feet high was placed in this recess and a second ring placed on top of it, both shell and ring securely held by extending the original anchor bolts. Another ring of 3-16-inch steel plate three feet high, 25 feet in diameter, was placed on the bottom as nearly concentric with the first ring as possible. The sand between the two rings was removed with an ejector operated by a water jet with a pressure of 160 pounds, using fire hose to conduct the water to the ejector. The space was then filled with concrete which was mixed on shore, and conveyed to the intake on a scow, then lowered with a self-dumping bucket that held about 8 cubic feet. Care was taken to lower the bucket to the bottom before dumping. This work was carried on from a raft anchored above the intake. The completion of this work cost $1,039.32.

In January of 1910 the mill was shut down for 36 hours. The lake at the time was very quiet and free from ice over the inlet, the ice field having drifted out. A boat was carried out over the ice hummocks formed on shore, (which sometimes built up from 12 to 20 feet) and with difficulty launched. The inlet screen was found covered with anchor or frazile ice from 16 to 20 inches thick; when barred loose it floated to the surface, the water draining from it like a sponge. Some of the pieces had a beautiful fern like structure, a picture of which is shown elsewhere. The pump could not be kept going by barring the ice from the screen, it reforming very rapidly. A one-half inch rope dipped into the water and removed after two minutes, attained a diameter of three inches by ice needles attaching themselves to the rope and building out in radial lines. Ice forming on the screen in this manner was undoubtedly the cause of many stoppages. In August, 1910, an inspection of the inlet showed two feet of the concrete collar above the sand bottom. This was considered safe and further raising unnecessary this year.

On January 2nd, 1911, the water flow of the intake was stopped entirely, and an inspection on the lake was impossible owing to the prevailing storms, but it was surmised the inlet shaft was partially filled with sand. The pump not operating the two preceding days, it was considered that very little sand was drawn into the tunnel, therefore, lowering the water in the shore shaft might cause the sand to flow forward and be taken out at the shore sump. A No. 11 Cameron pump was suspended in the shaft and the water lowered 38 feet but no water came in the tunnel. The weather in the meantime had moderated, making it possible to inspect the lake inlet from the ice field by placing planks to walk on. Soundings indicated two feet of sand over the inlet. A pointed pipe could be forced down its full length, from which it was concluded that a lot of the filling was slush ice heavy with sand. This proved to be true. A platform was placed on the ice, and a two-inch steam line run from the boiler house to the inlet. A four-inch pipe had already been forced down the intake shaft about 18 feet, into which the two-inch steam line was turned. Steam was admitted and this thawed some of the slush ice, making a depression in the sand over the inlet. It was then decided to use the four-inch pipe for the suction, of a four-inch steam syphon, and discharge the sand from the shaft. This proved so effective that another syphon was rigged up and operated. Arrangements were being made to run the syphons continuously, when someone reported a crack in the ice field near shore. Bars were driven into the ice and an attempt made to hold the field by extending ropes from them to the shore. We managed to save the syphons and the steam pipe, but the rest of the material went out with the ice. In the morning the ice field was again in shore and we made another start, but at noon the ice moved out. This time we made no effort to hold it, but saved our entire rigging. The ice stayed out a whole day and on its return we again rigged up, and had scarcely started work when the field once more drifted out. So far we had 12 feet of sand removed from the shaft, 22 feet remaining. The ice was too uncertain to depend upon and this plan was abandoned.

A pile driving derrick car was secured from the Copper Range Railroad, a track laid to the lake, a cut made through the ice hummocks, piling and bridge stringers secured. On January 13th, 1911, we drove six piles of the trestle and completed it from shore to inlet on the 16th. The ice field now seemed more regular in its habits and stayed in shore. On January 17th, the pile driver leads were removed and the derrick boom rigged with orange peel bucket. By this method the work of removing the sand from the shaft progressed very well. A small stream of surface water was turned into the pump well, raising the water there about four feet above lake level, and at 7:30 p. m., this water in the pump well ran out, thereby demonstrating that the tunnel was open.

On the 27th of the following, March, 1911, the inlet again filled with sand. A head frame of three-inch plank was erected over the inlet shaft as shown in Plate II, and used to place a ring of 3-16-inch steel plate, 8 feet high by 22 feet diameter, around the inlet. The sand was removed with ejectors operated by a water jet at 160 pounds pressure, and the shaft cleared of sand by April 10th. On April 14th, a storm carried away this head frame, the legs breaking first, also crushing the steel ring. After the storm abated the wrecked 3-16-inch plate was removed and straightened. Another head frame of green birch poles was erected. The 22-foot ring was again put in place, also the inner ring, 9 feet in diameter, the space between cleaned out and concrete raised six feet below lake level. The inlet shaft was again cleaned out and on April 26, milling operations resumed.

The intake plans for the future called for a 600-foot extension to the present tunnel; a temporary water supply through an open cut in the waste sands to the pump well; and the locating of a favorable place in bottom of lake for end of tunnel by means of test pipes. The open cut was excavated by shoveling, with sloping sides to lake level. Sheet piling was then driven down 3 feet below grade, from shore to pump house, a distance of 625 feet. The work was so conducted that the heavy cut near the pump was taken out and the rock between the well and the shore line blasted out to grade, before the sheet piling was all driven. This made it possible to remove the sand inside the sheet piling below the lake level from the pump well towards the shore, permitting all the water made by the excavation to flow towards the pump well where it was removed with a syphon. This cut was started on April 11th, 1911, and on June 10th, the water from it was being used to operate the mill. The cost of this temporary water supply was $8,929.58. A stout timber bulkhead was placed in the pump well to isolate the shaft from the new open cut water channel.

The concrete collar around the inlet shaft was now raised above lake level by means of steel rings and concrete filling, and an attempt made to pump out the tunnel with a No. 11 Cameron pump. This could not be done due to excessive leaks through the concrete collar at the inlet. It was decided therefore, to put a concrete plug in the shaft over the steel frame that was designed to carry the sheaves, to be used for hoisting the cage in shaft No. 2. Four two-inch rods carried this steel frame, shown on Plate III. The water was kept down below the steel while two courses of hemlock plank were fitted in the rock, and concrete put in place. This was allowed to set one week. The engineers in the meantime had located a point for No. 2 shaft on our concrete collar by triangulation, plumbed down and established points on the under side of the hemlock plank for the new workings. This also gave an opportunity to close up their survey of the old tunnel after it would be cleaned out. The shaft was again pumped out with a flow of only 200 gallons per minute. This permitted an examination of the tunnel which was found one-half filled with sand, and the small amount of timbering mostly down. In some places it was down on the up stream side only, forming an excellent dam and thereby nearly closing off the water. The hanging was down three and one-half feet in some places and quantities of loose rock had to be barred down. The tunnel was timbered following the clearing and completed in August at a cost of $6,361.85, which includes cost of timbering and a charge of $1,079.10 for power.

Ten test holes had been driven in the overburden on the lake bottom at intervals extending 600 feet out from the old intake. The sandstone was found 33 feet below lake level 100 feet from the old shaft, and 66 feet below at the 600 foot point. The test holes between the old shaft and the 600 foot point, indicated an even grade. Soundings at the 600 foot point showed a depth of water 26 feet, and sand and gravel overburden of 40 feet. A hole here was carried down in the rock 23 feet and an iron bar cemented in. This hole showed that it would be necessary to sink shaft No. 2 to a depth of 57 feet. This was done at the end of the old tunnel, and was made large enough for a cage with a nine foot tram car and a ladder way. The work was done in eight hour shifts, with two drilling machines, two miners to each drill and four muckers, the muckers working ten hour shift. Sinking of this shaft was commenced Sept. 1, and completed Oct. 9th, at a cost of $3,937.90 including timbering and a charge of $597.30 for power, as well as all labor for installing hoisting engine, etc.

Drifting the No. 2 tunnel was started October 9th, and driven at the following rates: During October, 168 feet; November, 301 feet; December, 131 feet, reaching the iron bar on the 15th. This part of the work was completed at a cost of $8,691.14 including timbering and power cost of $1,079.10. A sump at the end of the tunnel was taken out 5 feet deep and fifty feet long. Fifty feet of the new tunnel was concreted owing to the rock being very badly shattered. The timbering was completed, rails taken up and hoisting engine and pumps removed by January 14, 1912, at a cost of $3,081.41. Before the tunnel was allowed to fill the air line was well secured, the end raised nearly to the timbering and fastened there. This was for the purpose of removing any anchor ice or other obstruction that might adhere to the screens on top of inlet pipes. The rails in the upper or No. 1 tunnel were now removed. In order to use the old inlet and tunnel until such a time as the new inlet pipes could be placed, it became necessary to remove the concrete plug heretofore mentioned in old shaft. Eleven holes were drilled into it and preparatory to blasting, the tunnel and shaft were cleaned of everything except a No. 11 Cameron pump. Then the eleven holes were blasted from above with a battery. From the known leak in the concrete collar it was estimated that the tunnel would fill with water in about four hours, but after blasting, it actually filled—both tunnel and shaft—in five minutes. Where the water came in so quickly will be shown later. Our mining captain and his force were then transferred to the Trimountain Stamp Mill where a shaft for a new tunnel was well under way.

Keeping the open cut clear at its inlet until the ice formed on the shore was the most disagreeable task we were saddled with. The shore line on the waste sands from the mills would shift with every storm, having been known to recede as much as 150 feet after a very heavy storm from one direction; a storm from another direction would partly build it up again, in any case throwing up heavy sand bars. To make provision against the fall storms so prevalent here, 200 feet of 48 inch riveted pipe was built of ¼ in. steel plate with heavy re-enforcing angles every 12 feet on the outside to help it withstand the crushing action of the ice.

The inlet to the open cut had been maintained 8 feet wide and 2 feet deep, but it was now cleaned out to a depth of 4 feet. The 200 feet of pipe had been previously bolted together on skids parallel with the shore, both ends being closed with wooden blind flanges. When the weather was favorable the pipe was rolled into the lake and floated into the open cut. The spreaders that kept the sheet piling apart were removed one at a time until seventy feet of the pipe was in the cut, when the sheet piling showed signs of giving away. The pipe was then allowed to fill and sink in place, and this seventy feet of the cut filled in. During this fall the storms were unusual and the shore line receded fully 150 feet, and it was found necessary to add 30 feet of pipe in the cut. When this addition was made, there was not velocity enough in the pipe to carry the sand through which accumulated, thereby cutting off the water supply. This made it necessary to blast off seventy feet of the outer end where the trouble was caused. The pipe then scoured itself clean with the head we had available. A shelter was built over the inner end of the pipe in which a fire could be built, to make the place warm enough for the crew that was kept busy days and some nights removing the sand carried in through the pipe. A three inch water main was laid to the shore, on which was maintained a pressure of 160 pounds, this water was used to operate two ejectors made of 4 inch tees and 3 inch pipe, each ejector had a gate valve in the discharge pipe. This valve was closed turning the water back through the suction pipe when a stick or other obstruction chocked the tee, which occured very often. To keep this cut open and install the 48 inch pipe cost approximately $4,802.92 covering a period of nine months while the canal was in use.

During the month of February, 1912, the cause of the tunnel filling so rapidly after blasting out the concrete plug was discovered. As shown on plate IV the concrete collar around the inlet was raised four different times, the first time in 1902 when the opening was made into the tunnel, the second in September, 1909, the third in April 1911, the fourth and last time June 1911. After placing the outer shield in April 1911, for the concrete form, on the sand around the inlet, it was necessary for the diver to remove the sand down to the old concrete. This sand had been handled so much during the past winter and spring, that a concentration of slime and pieces of water logged wood had taken place around the inlet, thereby making it very difficult to clean the place out. As soon as the diver thought he had enough of the old concrete exposed to form a base for the new concrete to rest upon, it was covered by small sections at a time. By this process it was expected that the sand would only be in small pockets and so retained by the concrete. This was true when we pumped out the shaft, no excessive leaks showing. After the plug was put in the shaft, the wave action scoured out the sand spots in between the 1909 concrete and the concrete placed on it. To place the inner steel shield in position the bottom of it was made 1½" less in diameter than the ring already in place. This allowed free access of water and possibly sand. In the spring of 1912 to secure the shaft from this temporarily, the diver drove fine wedges all around, making the inner lining practically sand tight. About one third of the fourth section of the concrete collar was now taken off to allow the water to flow into No 2 shaft, and the open cut was discontinued.

In May, 1912, ½x74x118 inch steel plate was purchased and 2 pipes 36 inches in diameter, each 43 feet 4 inch long were made. These were fitted with steel flanges on one end and steel drive shoes on the other. Longtitudinal and butt straps were placed on the inside, and all rivets countersunk on the outside. Four sections were also made, each 6 feet 2 inches long, one of which had a steel flange on one end. Each section had the straight seam riveted and the butt strap riveted on one end, so the four sections could be slipped together and then bolted. With these provisions one section could be made from the four 24 feet 8 inches long, and bolted to either long section. While the pipe was being made, eight piles were jetted down in the overburden on the lake bottom over the end of the 600 foot new tunnel, and a platform was erected on them, 53 feet by 27 feet, and ten feet above the lake level. A head frame 20 feet high was placed on this platform, also the 5x8 inch Lidgerwood Friction drum hoisting engine used in the tunnel to hoist the cage in the No. 2 shaft. A five inch water main was laid on lake bottom from the shore to the platform, also a 1½ inch air line to operate the engine. Air was furnished by the compressor used for tunnel purposes. The five inch test pipe left in the lake bottom was extended to the water level and a set of blocks and tackle suspended from the head frame just over the point located for the 36 inch intake pipe. After clearing the top of the overburden of all large boulders which were lying at this point, one of the 43 feet 4 inch sections of pipe, with ends blanked, was rolled into the water, towed out and fastened to the suspended tackle blocks, pulled up and the bottom head removed. When the pipe was lowered to the lake bottom it stood plumb and in proper place. In this position a frame or guide was made for it at the top through which it could move down. The top flange was removed and three 2½ inch water jets were put in. The jets lowered the pipe 15 feet in 15 minutes, the water being turned off when the flange neared the water level. Two of the short sections were then bolted on, the pipe loaded with six tons of old stamp shoes, and the water again turned on. The pipe went down fairly straight, but if showing any tendency to list, the tackle was held, and the pipe suspended in the boil until it became plumb again. The water washed out all the fine sand, while the gravel and large boulders accumulated at the bottom. To remove the coarse sand and gravel a six inch air lift was used, while the large boulders, some of which weighed 300 pounds, were taken out by the diver.

The pipe was then driven with a 2,000 pound weight, the cleaning and driving continuing until sandstone was reached. A 12 inch pipe with guides to centre it was then lowered down the large pipe. Into this a single bit, 12 inch drill, with stem rising to the platform was introduced to drill a pilot hole to the tunnel. This was followed by a special reamer 34 inches in diameter, made of cast steel with 12 taper holes drilled into the bottom, the holes being fitted with twelve steel cutters. The hole was churned with this reamer, by using the friction drum of the hoist to actuate it, a 14 inch drop being maintained. By this method one hole was drilled and reamed in five days. After the drilling was completed the air lock from the Trimountain Mill caisson was fitted to the top of the pipe. A pneumatic chipping hammer was used to trim off the rock on the sides for about two feet to clear the steel shoes, and the 36 inch pipes were then driven into the rock. Screens 12 inches high were placed on each pipe.

This work on the intake pipes cost for labor and supplies $5,565.07.

The Champion Copper Company has been in operation on the shores of Lake Superior for ten years and during that time they have spent for water supply as follows:

	Labor.	Supplies.	Total.
Cost of the first intake tunnel....			$26,389.62
Extending Tunnel Itemized Below—			
Raising outer shaft 4 feet during September, 1909 ....$	610.17	$ 429.15	$ 1,039.32
Cleaning out intake shaft during January, 1911	1,561.71	588.65	2,150.36
Raising outer shaft 4 feet 9 inches during April, 1911	2,281.39	573.37	2,854.76
Cleaning out intake shaft during March, 1911	395.45		395.45
Construction of temporary intake canal	6,025.70	2,903.88	8,929.58
Raising outer shaft to lake level, 9 feet, 3 inches, during June, 1911, and putting in concrete plug in shaft	1,566.00	785.41	2,351.41
Constructing head-frame, engine house, placing engines, compressor, piping, etc., preliminary to tunnel work...........	2,655.00	833.86	3,488.86
Cleaning out and timbering old tunnel, June, July, August....	4,304.27	2,057.59	6,361.86
Sinking and timbering outer shaft, and drifting 20 feet....	2,908.80	1,029.10	3,937.90
Drifting tunnel, October 9th to December 15th, 1911.........	6,428.36	2,262.78	8,691.14
Finishing sump, tearing out track, etc..	2,980.75	100.66	3,081.41
Reopening old tunnel at outer shaft, February, 1912	456.95	14.84	471.79
Sinking two 36-inch pipes through 43 feet overburden, and drilling two 34-inch holes through 20 feet sandstone into tunnel, May, June, July and August, 1912	3,661.13	1,903.94	5,565.07
Sundries—			
Maintenance of intake canal while in use and laying large intake pipe	1,821.87	2,981.05	4,802.92
Taking soundings, locating sandstone, end of tunnel, etc......	1,007.65	637.38	1,645.03
	$38,665.20	$17,101.66	$82,156.48

The work described in this paper has all been done by the companies' employes working under the direction of their foremen. The diving and work under compressed air was done at the Trimountain Mill by Oscar Johnson, Master Mechanic, and at the Champion Mill by Herman Stealow, Surface Foreman. The mining work has been under Captain John O. Peterson.