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The Canadian Society of Civil Engineers.

INCORPORATED 1887.

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ELEVATOR CONSTRUCTION

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Read at a General Section Meeting, October 16, 1913.

The question of storing grain is probably as old as civilization. Since the time when men began to cultivate the land the resulting crop had to be held at least a twelve-month. Later on, the necessity of making the crops of a bountiful year last over into lean years lead to the storage of the grain for longer periods.

Illustration No. 1, is taken from a wall painting in the Tombs in Thebes. It shows two granaries with conical domes that were used at one of the large houses.

Illustration No. 2 is a cross section of some silos that were used by the early Egyptians, also taken from a recently discovered wall painting. In this are shown all the fundamentals of the grain elevator. The grain was received in the pile at the right of the picture and measured in a measuring basket by the man on the right. It was then carried by the other men walking up the stairs to the top of the bins, from which primitive elevators the modern term elevator leg has been derived. The grain was poured in at the top and taken out at the bottom when required, and the markings on the bin walls are supposed to indicate the character of the grain. The bins were not two-story affairs, as might be judged from the illustration; the Egyptian method of showing that there was something in the background was to place it on top of what was in the foreground. Simple as this process is it conveys the idea of the modern elevator. The grain was received, weighed or measured, put into the different bins according to grade and taken out at the bottom.

Prescott in his "Conquest of Peru" mentions that the Incas stored grain and that they sometimes had on hand a supply which would last the immediate neighbourhood for ten years.

An elevator as built at present provides means for receiving the grain, places in which to put it and appliances for delivering it. It also provides machinery for weighing it both when it is received and when it is delivered.

Fig. 3 will serve to illustrate the characteristics of an elevator, the receiving and shipping parts being separated and more clearly shown than in some of the other houses. In this illustration the grain is received from a vessel and elevated by means of a leg, which is simply an endless belt with cups on it. The leg discharges the grain at the top into a small chamber in which it is weighed and then spouted into the bottom of another elevator leg, which takes it to the top of the building and discharges it into a system of spouts which distribute it with the assistance of a system of belt conveyors to the various bins in the storage part of the house. When it is desired to ship, the grain is spouted out of the bottom of the bins on to a belt conveyor, which carries it to the working house where it is elevated to the top, discharged into a garner under which a weighing chamber is located resting on a scale capable of weighing a car load at a time. From this scale it is spouted into the carloading spout which drops it into the car. In this house there are two marine legs, so that there are two streams going up to the top and appliances for distributing the grain to any part of the house. The process of unloading from the large lake vessels is rapid, each leg having a capacity of 20,000 bushels an hour on the dip or when the leg is first put into the vessel. The machine, however, cannot take 20,000 bushels an hour continuously out of a vessel, because it is impossible to get the grain to it at that rate; but there are devices, consisting of ship shovels and clean-up shovels, which transfer the grain from the ends of the hold of the vessel to the leg so as to keep the leg supplied with as nearly 20,000 bushels an hour as possible.

The shipping is a comparatively easy operation. One of the valves at the bottom of one of the bins is opened, letting the grain run down to one of the belt conveyors by which it is carried to the working house, where it is elevated to the top, weighed and dropped into a car. A car can be loaded in about three minutes. There are records of two legs loading 230 cars in fifteen hours using only two spouts. The average carload is 1,200 bushels.

There are several kinds of elevators, the design depending on the location, the local conditions and the business that is to be performed. Fig. 3 illustrates an elevator on Georgian Bay receiving from vessels and loading to cars. While there are facilities for unloading cars if necessary, the business of this elevator is to unload lake vessels and to load cars. At Fort William, on the other hand, the elevator receives from cars and ships to lake vessels. This condition requires large track sheds containing pits where cars are unloaded; the grain is then conveyed to the working house, elevated, weighed and distributed to the different bins. The shipping to vessels holding large cargoes makes it advisable to place the working house near the slip, so that the grain can be spouted into the hold of the vessel quickly. At Fort William steamers have been loaded with 200,000 bushels in one hour and fifty-eight minutes, or at the rate of about three thousand tons per hour.

The house illustrated in Fig. No. 3 unloaded a vessel containing 525,000 bushels in twenty-five hours, and the same house, it is understood, has since bettered that record.

The Fig. 3 shows part of a house at Port McNicoll. The original house held over two million bushels, and another of the same capacity has since been added to it. In the building of the first house 27,000 yards of concrete and 1,300 tons of steel were used. Fig. 4 shows the layout of the construction plant used in this work. The plant was located originally on an island, with a trestle half a mile long leading to the mainland. All the material had to be brought in. Owing to the difficulty of getting broken stone and sand in large quantities, it was decided to bring the gravel from a point on the railway about forty miles distant, and as this gravel contained a surplus of sand, a screening and washing plant was erected near the elevator site. The gravel was delivered by flat cars which were unloaded from an elevated track. Beneath the track there was a tunnel containing a belt conveyor, which carried the gravel to the screening plant, where it was separated into stone and sand. The surplus sand, together with such sand as was not required for concrete, was spouted to a waste pile. The stone and sand required for the work was carried from the washer to storage piles under which there was another conveyor in a tunnel. This conveyor carried the screened stone and sand up an incline to storage bins over each mixer, from which the material was dropped into a measuring box and thence into the mixer. There were four mixers on this work. In most cases the material was unloaded by hand, but after being once unloaded from the cars it was sent through the screening plant, and distributed around to the various mixers by means of belt conveyors.

An interesting problem arose during the construction of this building as to the proper mixture of cement, sand and stone to be used in the concrete. The cost of the cement delivered at the mixer was $1.38 per bbl. and that of the gravel unloaded in the pile at the elevated track 38 cents a yard. The screened stone after passing through the screening plant was worth $1.70. There was so much of the sand that it was not considered as having any value except for filling purposes, and the cost of the concrete mixture would depend on the allowance which the Railway Company might be willing to make for it. About thirty per cent. of the pit gravel delivered was stone and seventy per cent. was sand. After washing, a very good sand with about twenty-five per cent. of voids was obtained. The mixture under these conditions would cost from $3.25 to $3.71 per yard for 1-3-5 mixture, depending on what was allowed for the waste. If thirty cents were allowed it would cost $3.25, and if no allowance were made it would be $3.71. After figuring on what the different mixtures would cost with different allowances for the waste it was found that if twenty cents were granted the cost of a 1-3-2 mixture would be the same as a 1-3-6 mixture, a most unique condition.

During the construction the supply of stone failed and it was decided to put in sand, the only objection being that the mortar would stick and not run out of the buggies. It was, however, possible to use enough stone to keep the buggies clean. The material averaged $3.38 a yard for concrete when placed over the mixers. The arrangement for mixing was good, the mixer being placed directly under the bins and discharging to buckets in the hoist tower which carried the material to the top of the building. Concrete was deposited in the bin walls for 80 cents a yard from the mixer, making the cost of the concrete in the walls about $4.20.

The Port McNicoll elevator storage house covers one acre, the entire building being of concrete and steel. Recently another unit of the same size has been added.

Years ago elevators were built principally of wood, as it was the cheapest material. In fact, up to about the middle of the nineties very little else was used. The elevator builder in most cases developed from a good carpenter. Not much technical engineering talent was employed, the ingenuity displayed being that of the natural mechanic. These men knew very little about grain pressures, but they soon discovered what thicknesses of walls were required for bins of various sizes and that if the bins were built too high the timber below would crush. The construction was gradually developed so that the minimum amount of material was used to carry the loads safely. The result was that, in wooden elevators, loads were used that would not be tolerated by other engineers. For instance, the side pressure in some of the old wooden elevators was 600 or 700 pounds on oak. A strict interpretation of most city ordinances would make it necessary to add very materially to the amount of timber used in the ordinary wooden elevator. One of the reasons why such pressures can be used is that the load in the elevator is an ideal load. It comes on easily and is taken off easily, without shocks or jars of any kind.

To illustrate how closely men worked in those days, there was one elevator in which about 65 or 70 feet of cribbing was shown on the plans. The owner asked to have fifteen feet more put on. It was objected that the posts would shove up into the girders. He stated that he was only going to use the building to store oats, which was much lighter than wheat, and he, therefore, could afford to take a chance in building so much higher. The owner finally assumed all responsibility for the additional height and stated that he was not going to fill the elevator with anything but oats. Six months later the posts had gone two and a half inches into the timbers, and on investigation it was found that the first time the elevator was filled it was with wheat.

About the middle of the nineties there began to be a demand for the fire-proof elevator. The increase in insurance rates and in the cost of timber led to the inquiry as to whether something better than wood could not be obtained. Steel was first used, then tile, and afterwards concrete. About the time that the building of fire-proof elevators was proposed, those who were in the business of constructing elevators realized that they knew very little about grain pressures. It was all very well to build in wood, in connection with which experience had been gained, but in order to make a proper design for a building in steel, or tile, or concrete, it was very necessary to know what the side pressure and the down pressure and all pressures amounted to, at least, approximately. At that time knowledge with regard to bin pressure consisted of one fact. Someone had demonstrated that if a bin were filled with grain the pressure at the bottom would be about equal to the weight of grain in a cone with a base equal to the bottom, and of a height three diameters of the base. This was arrived at by experiment, but the side pressure was not known. It was found that after a bin was filled to a height of about three times the diameter of the base, it did not matter how much more was put in, because the pressure on the bottom did not increase, and from this it was an easy matter to demonstrate that the pressures on the side were uniform for each succeeding foot up from the bottom, until near the top; but the amount of these pressures was not known.

Everyone who thought about the matter knew that it had something to do with the friction of the grain on the wall, and, finally, it was found that it would take two pounds, at least, to hold a pound of grain against the wall. The pressure might be more than two pounds, but it could not be anything less. Many engineers engaged in the business made more or less correct experiments to determine the pressure. An experiment with a bin about eighteen inches square, with three sides solid and one side with wooden slats was made by the author. These slats were kept apart so that each acted independently. Each slat was tested with a centre load to find how much it would take to deflect it a certain amount, the stronger of the slats were selected and put at the bottom, and each one labelled with the load it would carry for a certain deflection. It was found that the side pressure was everywhere very nearly twice the weight of the grain held against the slat, but that as soon as a small hole in the bottom was opened and the grain allowed to trickle out, the slats bent a great deal more because of the change in conditions. It was estimated that the pressure on the bin walls when the grain was in motion was about three times the weight of the grain pressing against it. This very simple rule was adopted about the year 1898, and since then elevators have been built on that assumption. Although a lot of good work has been done in the investigation of grain pressure in more recent years the author has seen no occasion for changing this rule. It figures just a little more than some of the rules employed; a little more, possibly, than Mr. Jamieson's experiments, and is just a little safer. These experiments were followed with an experimental bin which was built in this city before the Windmill Point elevator was put up, and from that bin the pressures were determined.

In the experiments with the small bin with the slats on one side of it one peculiarity was especially noticed. The bin was filled up to the top, struck off level, and then a slide opened on the bottom and a portion of the grain allowed to run out. The slats on the side bulged out, making the bin a little bigger. The grain, however, that had been taken out at the bottom could not be put in at the top without heaping. This showed that when the grain fell into the bin it packed pretty well near the bottom, and when the bottom slides opened and allowed some of the grain to flow out there was an area of grain in the immediate neighbourhood of the opening less dense than the grain in other parts of the bin. With a glass side in the bin it was possible to see the grain arch over. The point where the little kernels held up the under side of the arch could be seen, and as the grain went out at the bottom the under side of the arch crumbled off. The pull of the grain on any obstruction that meets its path in the bin is quite strong. In steel elevators considerable difficulty has been experienced because the tie bars across the bins pulled out the rivets. Apparently enough rivets were figured for the strain due to the load on the edge of the bars, but the suction of grain on the side of the five-inch flat bars would pull them down, twist them over and pull the rivets off. Of course, this was not so apparent with round bars. In one case of round bars, an elevator was built with bins that were twelve feet by twenty-four feet, and about seventy feet deep, rodded in the middle. There were two openings in the bin, one in the centre of each of the twelve feet square portions of the bottom, and these rods, of course, were in a line up the middle of the bin. The builder of that elevator was apparently afraid of the suction of the grain on the rods, and in order to overcome it 6 x 6 posts were put up in the centre of the bin to support each rod so that the down pull of the grain would not break the rod. Whenever the valve at one side of these rods was opened at the bottom of the bin there was a suction of the grain sideways, and it was found that the 6 x 6 posts would not stand. The posts were, therefore, taken out and 8 x 8 posts substituted. These also did not stand the strain. The owner was advised to take the posts out and there was no more trouble. The action is very simple. When the hole in the left-hand side was opened the grain coming across pushed over the posts, and instead of the posts helping the rods they pulled them down.

The building of the bins is probably the most interesting feature in the construction of a grain elevator. It was the feature which required the most careful consideration when the change from the wooden house to the concrete elevator took place.

Figures No. 5 and No. 6 are illustrations of the manner in which an elevator is being built at the present time in Manchester, England. The bins are of concrete, rectangular in plan, and about 70 feet deep, some kind of a shutter form being used. The reinforcing is both vertical and horizontal, and the vertical reinforcing is spaced so closely that looking at the picture it would appear almost impossible for the workmen to get from one part to another. The progress on this work is about 18 inches vertical, per week, and at this rate it will take eleven months to put up the bin walls.

Fig. No. 7 illustrates how elevator building is done on this side of the water. It is a picture of the forms for some bins erected at Fort William. The bins are circular in plan, the cylinders being placed in contact with each other, and the small spaces between the cylinders being used for storage of grain. On this form a man may walk anywhere over the entire area covered by the structure, and may wheel concrete and deposit it in any of these walls directly from buggies. The moving form, about four feet deep, goes around the outside and inside of the bin walls and is held together by yokes of some kind that span the wall above the level of the form proper. A jacking device is attached to the form so that it can be lifted up as the work progresses. The concrete is poured into the form and the form moved up continuously. This part of the work may be executed in different ways. Some use a plain round rod with a jack that clamps the rod, and the form simply climbs up on the rod leaving the rod in the wall. On the forms shown in the illustration, rods threaded the entire length were used with an ordinary nut and nut holder, with means to turn the nuts so as to lift the form as the work progressed.

Fig. No. 8 is a view looking out over the top of the forms at Port McNicoll; the bins are thirty-three feet in diameter with walls eight inches thick.

Fig. No. 9 is the same work viewed from the other side of the slip, showing the forms part way up. The first section of the building is shown to the right. The second section was put up last summer. The illustration shows the arrangement for conveying the material over to two towers, from which it was spouted out to carts and distributed over the area.

Fig. No. 10 is a picture of the same set of bins after the forms had been removed and the steel work was being erected on top of them. These bins hold in the neighbourhood of forty-eight thousand bushels of wheat each.

Fig. No. 11 shows some forms being erected in Montreal harbour for Elevator No. 1. These forms were run up ninety-six feet in fifteen days, about six feet four inches a day. The distance that a moving form may be raised, or the amount of a bin wall that can be built in a day, depends on a great many elements. For instance, if the building under construction is very large, the difficulty of getting a sufficient amount of material on the work in twenty-four hours is probably the controlling feature. When the building is not very large, the rapidity with which the material will set up is the controlling feature. In warm weather, with a small job, it is possible to put in over ten feet a day. This summer at Lawrenceburg, Ind., on a small building, the walls were run up ten feet five inches in twenty-four hours. That is going just a little too fast because there is danger of the concrete falling out of the forms at the bottom. Six feet can be put in with safety in warm weather, and, in cold weather, the progress must be much slower. The bottoms of the forms should be watched to see that the concrete is setting up sufficiently to sustain the load above it.

Fig. No. 12 is another view of the Harbour Elevator No. 1, showing the height to which the forms had been raised in just one week's work. The dark line indicates that this material was not set up very hard. It dries out on one side faster than on the other, probably depending on exposure to the sun.

Fig. No. 13 shows the same work two weeks later, with the forms removed from the top of the bins and about ready for the steel.

Fig. No. 14 is a view at the other end of Elevator No. 1, showing eighteen bins on the land side. The scaffold shown below the form is for the men to go around and point up any defects which may appear in the wall as soon as the wall is uncovered by the gradual upward movement of the forms. One of the difficulties in building in a location such as that shown in the picture is due to the restricted space and absence of any place in which to store a large amount of material so that a number of bins can be built at one time. The reason for cutting this particular work in two and building one part first and then the other was that it was impossible to get enough material on the ground to build everything at once.

Fig. No. 15 is another view of the same kind of building at St. John, N.B. This particular picture was taken on June 18th, four days after the moving forms were started, and two weeks later (Fig. No. 16) the building was seventy feet high. It went up fifty-three feet in two weeks. One of the troubles was to get enough material to keep the work going as fast as was otherwise possible.

A word should be said about the marine towers shown in Fig. No. 18, which is an elevator at Tiffin, Ont. These towers are 28 x 32 feet and 150 feet high. They run on two tracks and have a mechanism to propel them along the wharf. Each tower is supported by forty car wheels and weighs about 650 tons,—quite a bulky thing to move around. It is moved longitudinally in order that it may get into various hatches and holds of vessels, so that if one tower gets through its work ahead of another it can move to another hatch. One of the principal troubles with the tower is to hold it against the wind pressure, which is quite great on a structure so high. The tower is held back to the storage building by a travelling guide which is about thirty feet long. These towers are supplied, at intervals along the wharf, with various places at which to lock in case of storm, and have a propelling mechanism which will take them against a ten pound wind; if the wind is stronger than that the towers have to remain in one place. A tower of this kind is also supplied with mechanism to raise, lower and place the marine leg in any position in the hold of a boat. This marine leg is eighty feet long and weighs with its boom, thirty-one tons. Power to operate the ship and clean-up shovels is supplied from the tower, and the grain is weighed in the tower as it is received. The towers shown have scales for weighing 400 bushels of wheat at each draft; later ones have been fitted with 1,000 bushel scales, which means that the scale man will have to weigh twenty times an hour.

Referring again to Fig. No. 3; on the extreme left is shown the spout for loading grain into cars. The scale shown above the bins weighs an entire carload at one draft (up to 2,000 bushels of wheat) and drops it directly through the car spout into the car. The impetus gained in this drop is enough to shoot the grain clear to the ends of the car from the centre door by means of a bi-furcated arrangement at the bottom of the spout, and no trimming is required. In the early days of these spouts they sometimes failed to work. They were then built of wood and the old millwrights used to say, "When it is smoothed up it will work all right." If one was built which did not work they would wait, and after awhile it would work all right. This kind of reasoning was accepted for a long time, but occasionally one would not "smooth out," and there was doubt as to why it would not work. Something on it would be changed and then it would work.

The difficulty was finally ascertained to be that the spouts were so well made as to be air tight when new and the grain was retarded in its flow owing to the creation of a partial vacuum.

The first grain elevator in Chicago, built in 1838, is shown in Fig. No. 17. It was simply an old warehouse, with an elevator leg put in it, a belt with buckets on it, and at the top one horse-power (literally, as a horse on a treadmill furnished power) which elevated grain to the top of the building where it was spouted on to the floor. Holes were cut in the floors to let the grain fall down on to the next story. The spouts leading out to the vessels show that grain was then carried in bulk instead of in sacks. Quite a number of old buildings were used in that way. In one case an old dwelling house in St. Louis was used to store grain. The building stood while it was filled, but when the grain was being drawn off in the spring, it collapsed.

Fig. No. 19 is the picture of a concrete elevator at Ogdensburg. The only peculiarity about it is that the marine tower shown on the side was built with a moving form, and put up at the same time that the bin wall was constructed. It was a pretty piece of work and very expensive.

Figs. No. 20 and No. 21 show the complete house at Victoria Harbour, Port McNicoll, including the power plant and the concrete stack. This concrete stack has no cracks in it. One was built before that had a great many cracks, the reason being that there was not enough concrete in the stack. It was erected by a stack builder who prior to making the specifications had examined a large number of stacks and found that they were all more or less cracked. The theory upon which these stacks were built was that enough steel was put in them to take the tension and enough concrete to take the compression. As a matter of fact, in building a concrete stack enough steel should be put in to take the tension if the concrete cracks, and then enough concrete to take the tension anyway. At least the tension on the combined section of the concrete and steel should be low enough to prevent the concrete from cracking. The walls of a concrete stack would, under these conditions, be twice as thick as those made by the ordinary stack builder.

Fig. No. 22 is a picture of Harbour Elevator No. 2, Montreal, an elevator of two and a half million bushels capacity, all concrete; in fact, the largest all concrete building in the world. It required 44,000 yards concrete and 2,900 tons reinforcing steel. It has an unloading capacity from cars of about 250 cars in ten hours, 40,000 bushels per hour from boats with its two marine legs, one on each side of the tower shown in the foreground, a shipping capacity of 90,000 bushels per hour to boats, and is an entirely up-to-date house. This elevator, with the Windmill Point and Harbour Commissioners No. 1 Elevator and their shipping galleries, makes Montreal the best equipped ocean grain harbour in the world. The equipment, however, is not sufficient for the demands of the port.

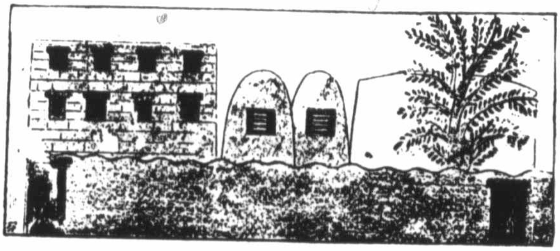


Fig. 1

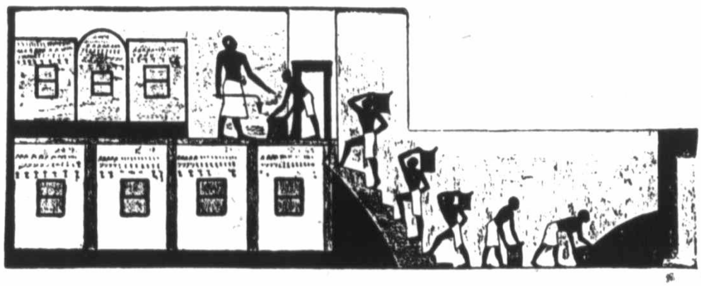
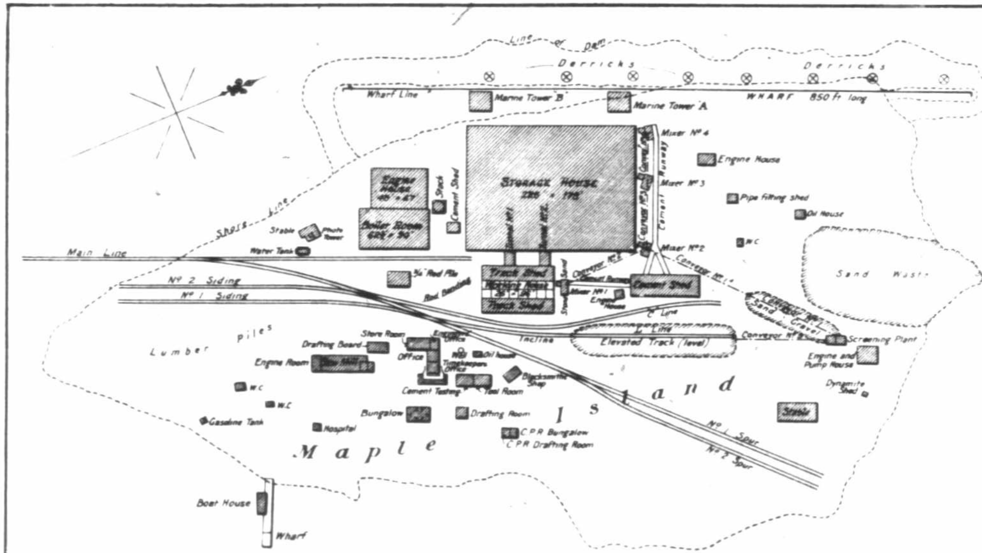


Fig. 2



LAYOUT

FOR THE CONSTRUCTION OF

C. P. R. ELEVATOR

Victoria Harbour

ONTARIO

Fig. 5

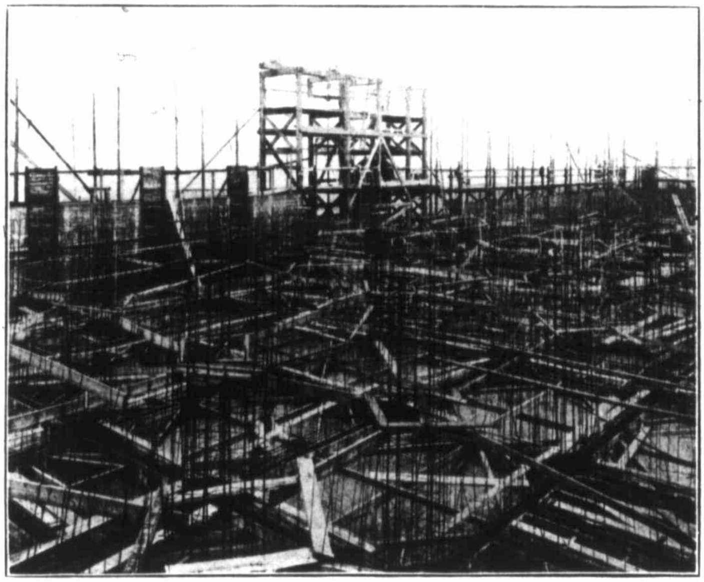


Fig. 6

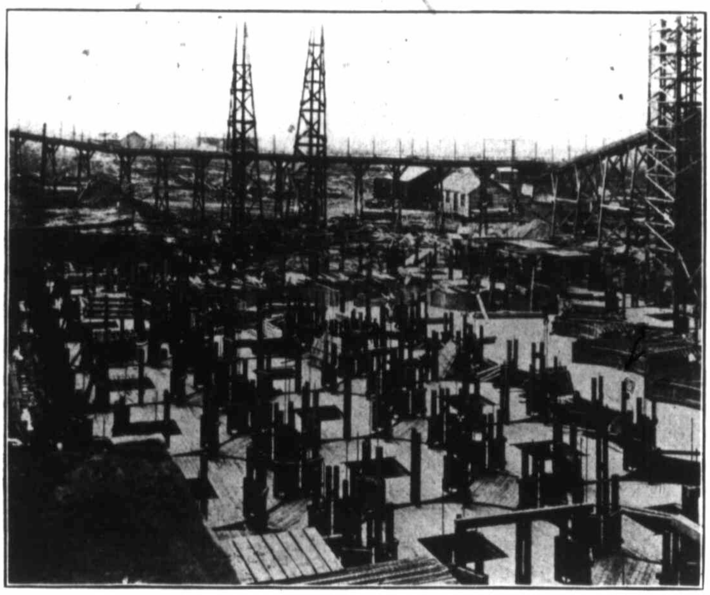


Fig. 7

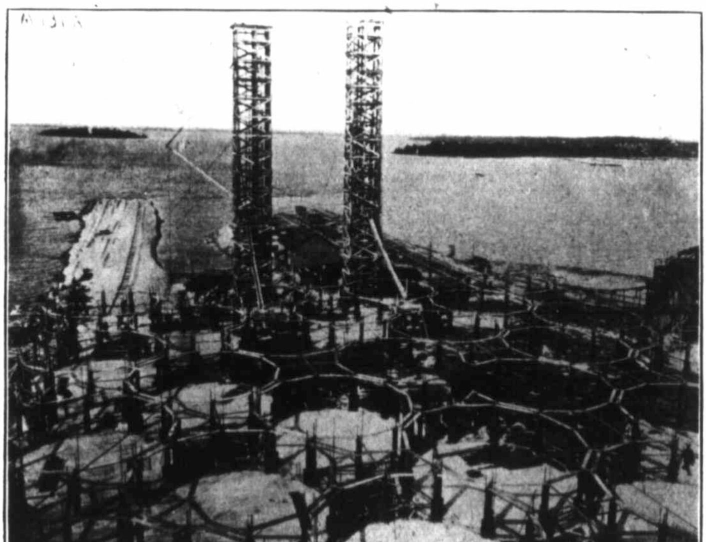


Fig. 8

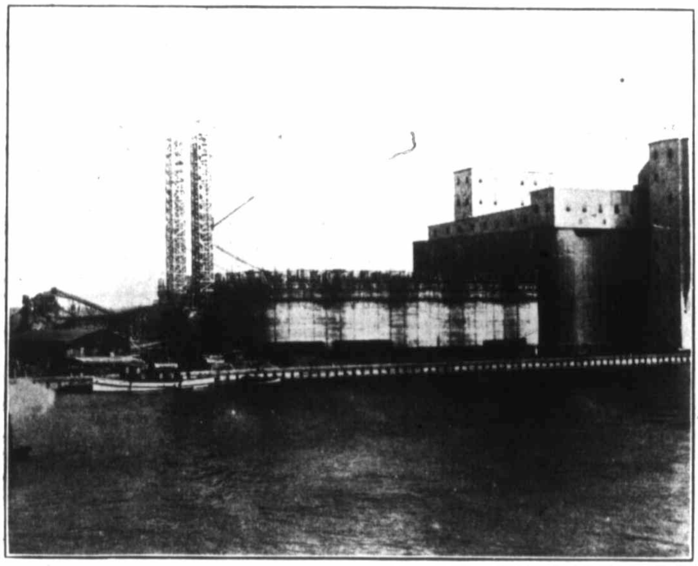


Fig. 9

Fig. 10

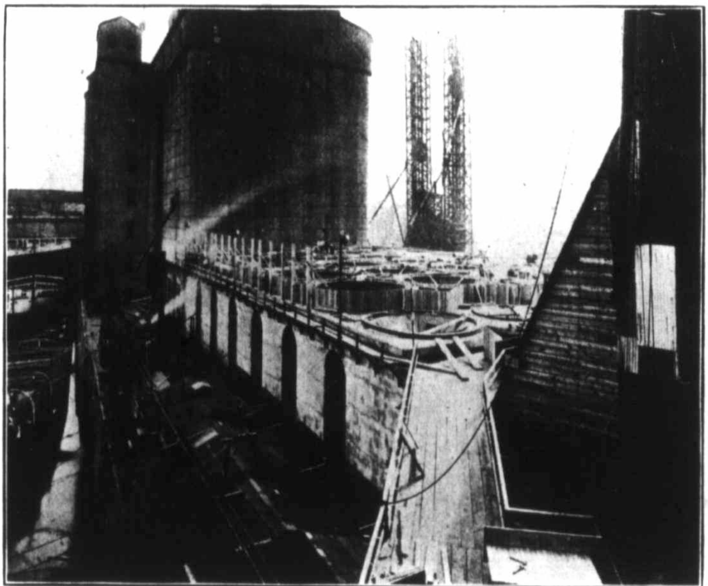


Fig. 11

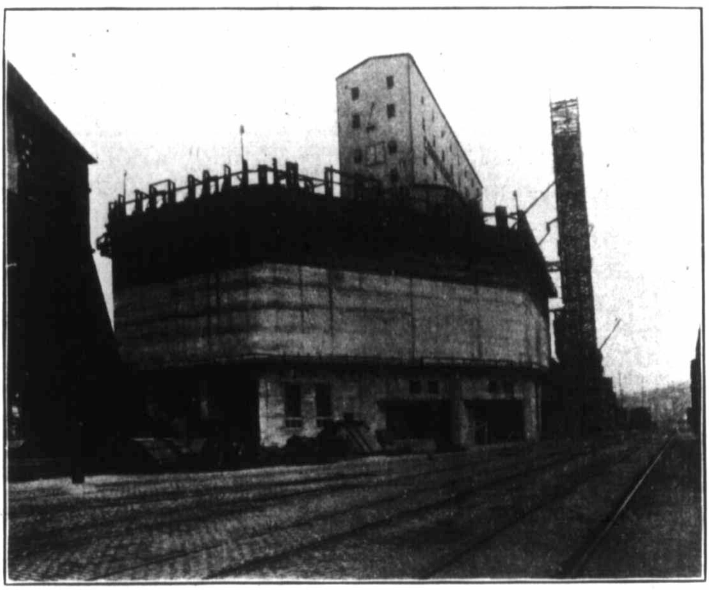


Fig. 12

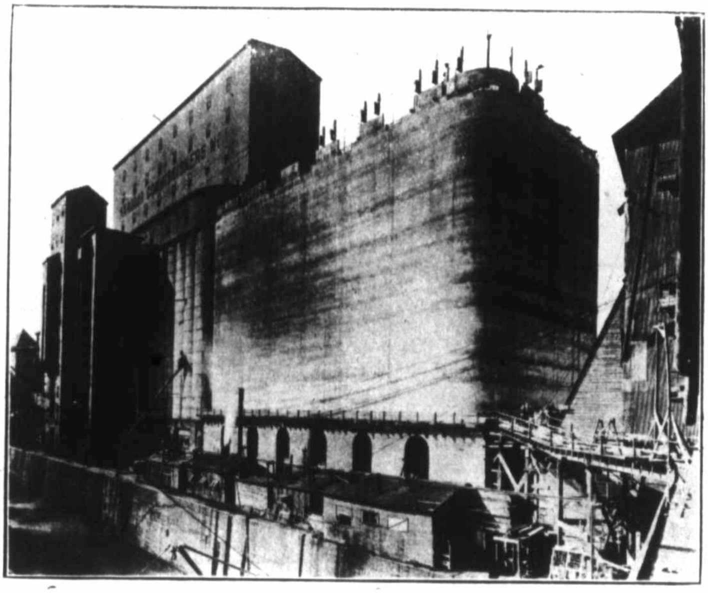


Fig. 13

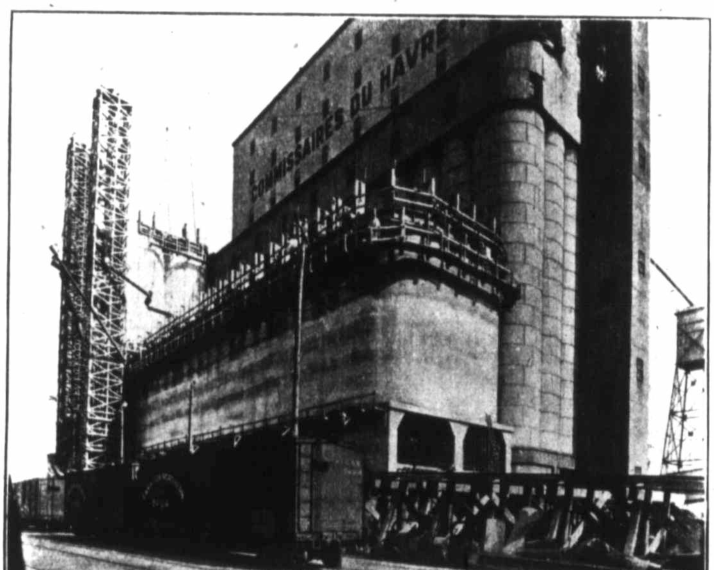


Fig. 14

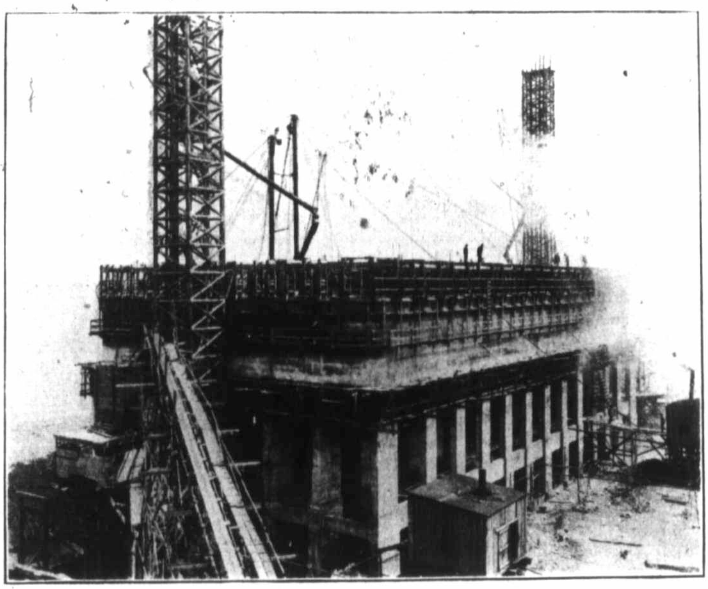


Fig. 15

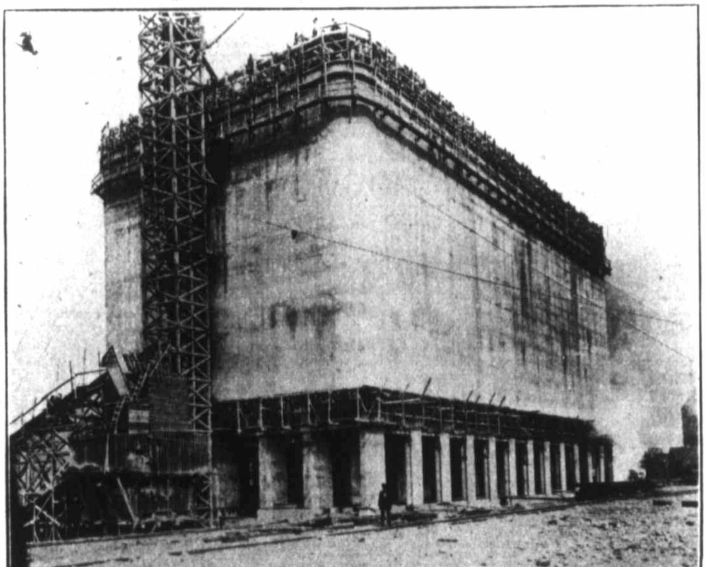


Fig. 16

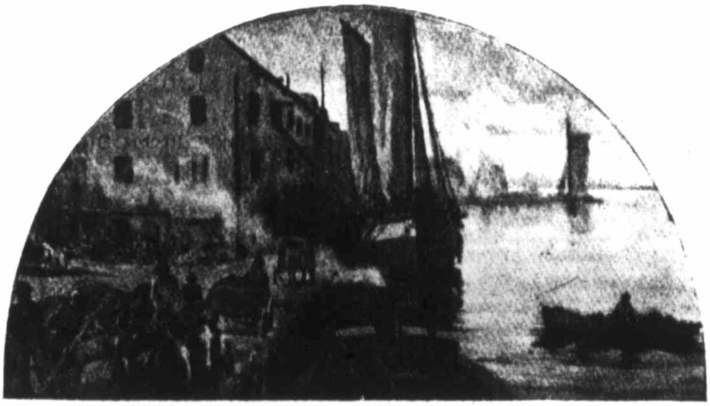


Fig. 17

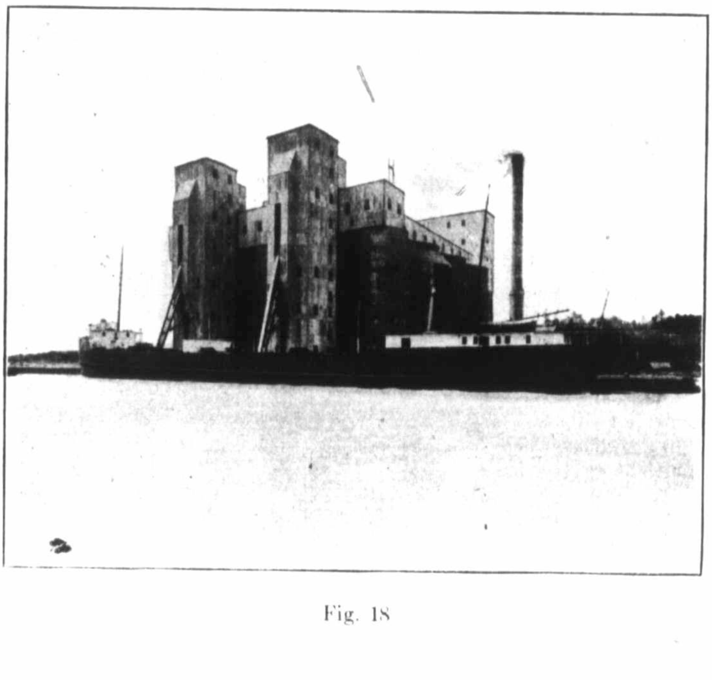


Fig. 18

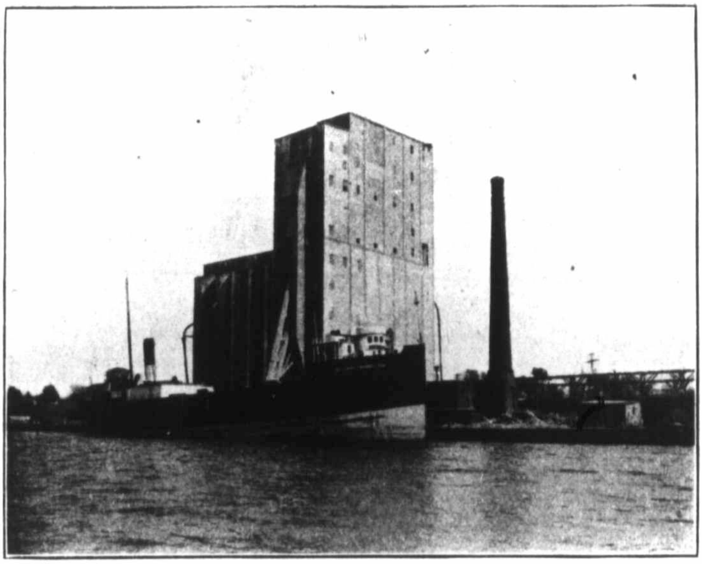


Fig. 19

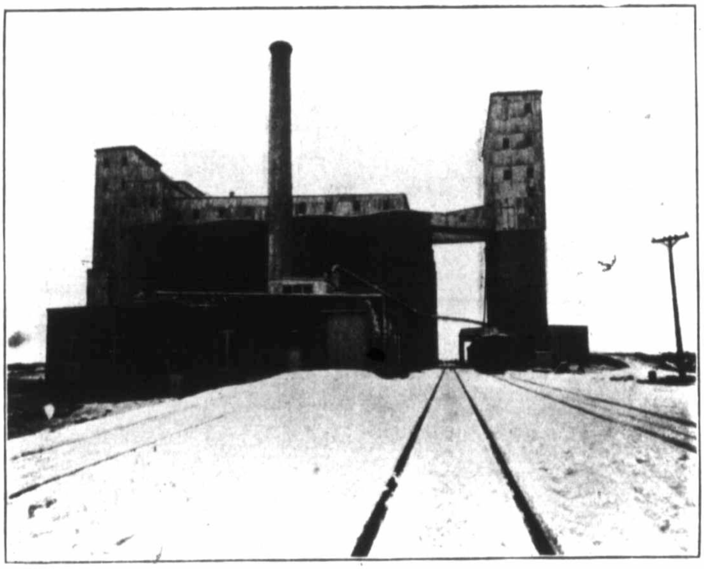


Fig. 20

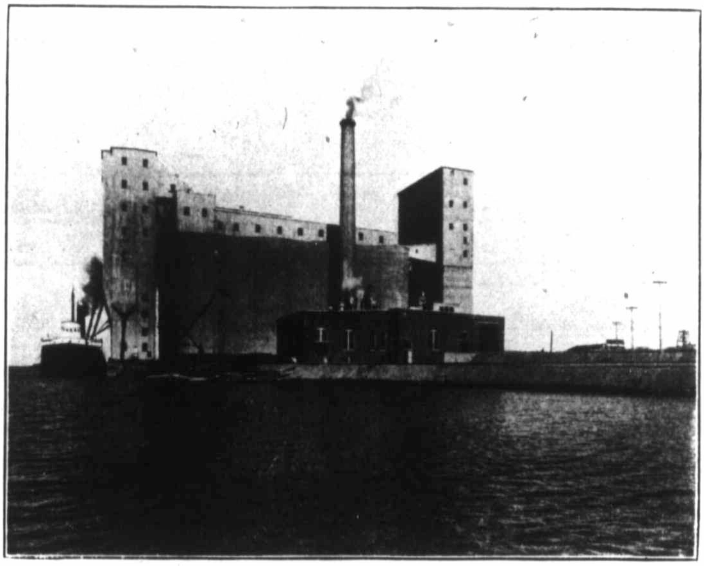


Fig. 21

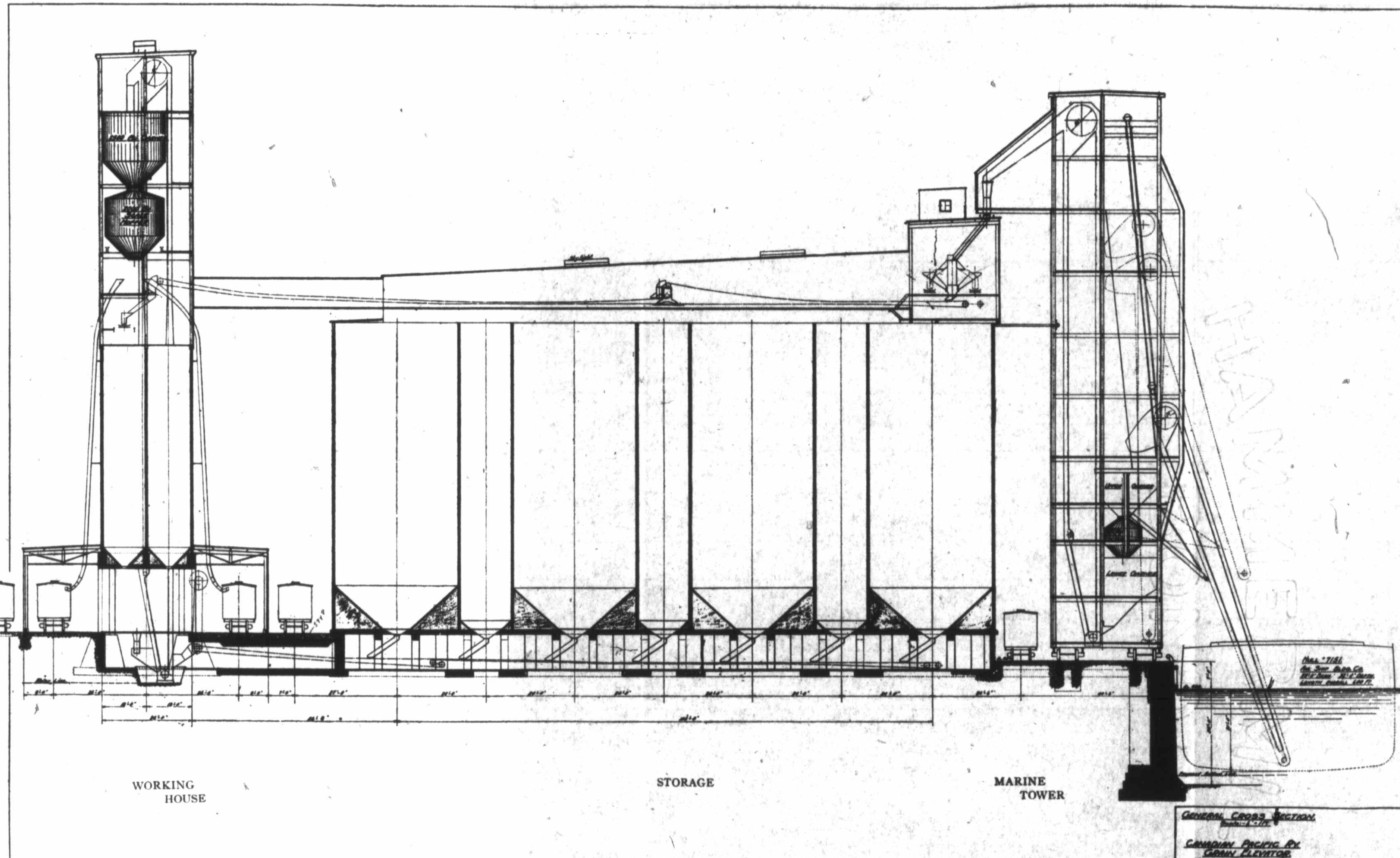

WORKING HOUSE
STORAGE
MARINE TOWER
GENERAL CROSS SECTION
CANADIAN PACIFIC RY.
GRAIN ELEVATOR
4

Fig. 3