KETCHAM

Steel Structures for Mines

Civil Engineering

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STEEL STRUCTURES FOR MINES

BY

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Milo Smith Ketchum, B.S.,

ENTITLED Steel Structures for Mines

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Civil Engineer.

Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering.

S T E E L C O N S T R U C T I O N F O R M I N E S.

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Within the last few years the use of steel for structures for mines has been growing and has become quite general even where suitable timber can be obtained at a low price. For large head frames and heavy buildings the cost of using steel before the present rise in price of that material has often been the same or less than the cost of a timber structure of the same strength and rigidity. In minor structures the first cost has usually been in favor of the timber structure, but the greater durability and saving in insurance and risk of loss in case of destruction by fire have been more than sufficient to cause mining companies to adopt steel construction for all classes and types of mine structures. The building is usually the least expensive part of a mining plant and the saving in insurance on the expensive machinery by installing it in a fire proof structure is often sufficient to pay a good rate of interest on the entire first cost of the building. For example the expenditure of $100,000 for steel buildings at the Golden Gate Mill at Mercur, Utah, enabled them to save $8000 yearly in insurance on their expensive plant. Besides the saving in insurance there is an increased security from fire in case of strikes. This latter item is more important than would at first appear, for miners are often composed of a class of men that will not shrink from burning a mill if they think it necessary to gain their end.

The increase in the use of steel has been so rapid that en-

gineers have hardly been able to keep pace with the demands, and as a consequence many of the steel mine structures have been very poorly designed. It is the intention in this thesis to describe several existing steel mine structures, to discuss their merits and defects, and finally to design several typical mine structures. Several of these structures described have been designed by the writer. The subject will be taken up under two principal heads, viz:- Head Works, and Mill and Mine Buildings.

H E A D   W O R K S.

By head works is meant the structure placed at the mouth of the shaft that supports the sheaves, hoisting gear, etc. Where the sheaves are supported by a frame, the head works is called a Head Frame or Gallows Frame, and where the sheave is placed at the top of an enclosed structure, it is called a Shaft House or Rock House.

The Head Frame sometimes supports ore bins: while the Shaft House contains screens, bins, rock crushers, etc. The first frames were usually built by ordinary carpenters who had no idea of the amount or direction of the stresses that members should be designed to take, and as a consequence many interesting structures are seen.

The type illustrated by Fig. 1 Plate I has been used in South Africa, in the collieries of Pennsylvania, in the iron and copper mines of Michigan, and iron mines of Wisconsin and Minnesota. The square main tower is elaborately braced with the sheaves resting near the ends of heavy timbers laid across the caps. The resultant of the stresses in the ropes falls between the braced tower and the back struts. A frame of this type is very wasteful of material, as

the members mostly act in flexure. Several large frames Montana, notably the Neversweat and High Ore frames 100 ft. from the center of sheaves to bottom of sill were designed like Fig. 2 Plate I. This type seems to be a step in the right direction, but it is really a poorer design for a wooden frame than Fig. 1, for the reason that with the main member inclined as shown it has been found practically impossible to obtain a rigid structure. The main member not being in the line of the resultant causes a waste of material. This type of frames has proved to be unsatisfactory where large quantities of ore were required to be handled and are being replaced by steel frames.

STEEL HEAD FRAMES. Head frames made of wrought and cast iron were used in Europe quite early. The frames were very cumberous, crude structures, and were, as far as the writer has been able to ascertain, comparatively small in size. One of the earliest, if not the earliest, head frame in the United States was built at the Oakwood shaft of the Lehigh Valley Coal Co. See Fig. 5 Plate II. It is about 55 feet high, and is built of wrought-iron channel-bars laced. It was built about 1870, and is still giving good results after nearly thirty years of service. It has six posts, nearly vertical elaborately braced, without back braces.

Steel head frames were used in the early development of mining in South Africa. The first frames, partly on account of the cost of transporting large and heavy members were poorly designed, flimsy affairs. Lately better designed steel head frames have been put up at several shafts. The steel frame at Robison Deep Gold Mining Co., 85 feet high, shown in Plate III, is a typical South African frame, and follows the outline of the early wooden frames, Fig.1 Plate II. The main members are box columns made of four angles,

placed so the structure will appear massive. These frames have not proved to be entirely satisfactory, and the present tendency appears to be toward wood, which can be obtained more easily now than formerly. The timber frame shown in Fig. 2 Plate III is a good example of a modern South African frame.

Steel head frames have recently been built in England following the same general design as that of the Robinson Deep. As far as can be ascertained they are clumsy, uneconomical, and unsatisfactory.

Several steel frames of the braced tower type have been built in Pennsylvania, and have been very satisfactory; for example: Fig. 1 Plate II, built at Nanticoke, Pennsylvania for the Susquehanna Coal Co.; Fig 2 Plate II, 59' 6" high, built at Leggett's Creek Colliery for the Delaware and Hudson Coal Co.; Fig. 3 Plate II, 30' 0" high, built at Alden Station for the Alden Coal Co; Fig. 2 Plate IV built at Gilberton, Pennsylvania for the Philadelphia and Reading Coal and Iron Mines (described in Engineering News, November 10th, 1898). The braced tower type can be used to advantage where the shaft is divided into four compartments, as is the case at Gilberton, just referred to. This head frame is 66 ft. 6 in. high, 48 ft. long by 29 ft. wide at the base, and 18 ft. long by 16 ft. wide at the top. There are four rope sheaves at the top, each 12 ft. in diameter. Crucible steel ropes 2 in. in diameter are used. The ordinary hoisting speed is 2300 feet per minute. Frames No. 5 — eight 35 ft. 6 in. high, and nine 38 ft. 3-¼ in. high, Plate II, are very uneconomical, and were doubtless designed so that they could be erected while the wooden frames were still in place. Frame No. 7 Plate II, 61 ft. high, at the Prospect

Colliery of the Lehigh Valley Coal Co. was designed to hoist coal by placing the engines on either the front or back of the structure, and consequently is very heavy. Frame No. 4, 75 ft. high at Sugar Notch, Pennsylvania, for the Lehigh and Wilkes-Barre Coal Co., and frame No. 6, Plate II, 48 ft. high, at Newport Centre, Pa. for the Susquehanna Coal Co. are of the braced type and are the best designed head frames in the coal region.

The principal dimensions of frame No. 4 are as follows:- Height to sheave centre 75 ft., base 40 ft. 11-3/4 in. by 21 ft. 8-½ in. The leg A is made of two angles 5" x 3" x 3/8" down to the lowest horizontal brace, and from there to the base of two angles 5" x 3-½" x 3/8". The leg B is built of two angles 6" x 6" x ½". The diagonal braces C are single angles 3" x 3" x 3/8". The horizontal braces are designed to take the wind stresses.

In calculating the stress in the members of the frame, a live load of 30,000 lbs. acting alternately on each hoist was assumed, and a dead load equal to the weight of the structure. A wind pressure of 25 lbs. per square foot of vertical projection was assumed. Unit stresses for tension in posts and bracing were taken at 5,000 lbs. per square inch, for live load, 10,000 lbs. per square inch for dead load, and 15,000 lbs. per square inch for wind load. The extreme fibre stress in channels was taken at 7,500 lbs. per square inch. Columns were designed, using the formula

$$S = \frac{S_1}{1 + \frac{l^2}{36000 r^2}}$$

The principal dimensions of frame No. 6 are as follows:- Height to centre of sheave 48 ft.; base 33 ft. 10 in. by 56 ft. Each outside leg is made of two channels 12" x 25# laced, the middle

leg of two 15" x 45 # channels laced. The central upright posts are made of two channels 8" x 16-¼# laced. The end cross braces are 9" channels and the side cross braces are 8" channels.

The design called for a working stress on each pair of ropes of 60,000 lbs. in hoisting, and 20,000 lbs. in lowering. A factor of safety of 10 was used. Each pair of shafts, 1 & 2 and 3 & 4, are independent, and the stresses were calculated for the severest conditions of hoisting. The weight of the steel frame, independent of the sheaves, is 98,000 lbs.

One advantage of the "A" type is that it gives a strongly braced frame with a minimum amount of material. In case of over winding with the above frame, the cage car can go over the sheave without injuring the frame and with less loss of life than if the old scheme were used.

AURORA HEAD FRAME. The steel head frame at the Aurora Mine, Ironwood, Michigan, shown in Plate IV, is a good example of how not to design a frame. The hoisting engines are placed so that the hoisting ropes make an angle of about 20 degrees with the horizontal thus bringing the resultant of the stresses in the ropes entirely outside of the frame. Under ordinary conditions of hoisting the weight of the structure would probably be sufficient to prevent overturning without anchoring on the farther side. A maximum stress of 30,000 lbs. in each cable, however, would be certain to overturn the structure, unless the farther side was firmly anchored.

When seen by the writer in April, 1899, this frame was in operation and appeared to be quite rigid.

HIGH ORE AND NEVER SWEAT HEAD FRAMES. The steel frames at the High Ore and Never Sweat Mines of the Anaconda Mining Co.,

Butte, Montana, are essentially duplicates. The dimensions and sizes of the Never Sweat frame is shown in Plate V. The frames are 100 feet high and very heavy. They were designed and erected by the Gillette-Herzog Mfg. Co. of Minneapolis, Minnesota, in 1899. Ten-ton skips with 7" x ½" flat ropes are used. These loads are about 100 per cent larger than usual. These frames together weigh 610,000 lbs. including the hoppers. If the frames had been designed to take the actual loads, in place of following the instructions of the mining company, there would doubtless have been a saving of 100 per cent in material.

At 40 cents per hour the shop work on these frames cost 1.09¢ per pound. The actual cost of erection, everything being riveted, was $11.20 per ton.

ST. LAWRENCE HEAD FRAME. This frame, 90 feet high and weighing 130,000 pounds was the first steel frame erected in Butte, and was built by The Wellman-Seaver Engineering Company for the St. Lawrence Mine of the A.C.M.Co., Butte, Montana. It is of the "A" type and is very heavy. It is not properly designed and is not rigid, the members being too long and the bracing inadequate.

WEST COLUSA HEAD FRAME. This frame, 50 feet high, and weighing 65,000 lbs. was the second steel frame in Butte. It was built at the West Colusa Mine, Butte, Montana, according to the plans prepared by the engineers of the Bostana & Montana Mining Co., and was found to lack stiffness and rigidity. To strengthen it wooden braces were inserted after erection. It is of the "A" type; the back braces being made of box columns of four angles, and are not cross braced in any way. This as well as the St. Lawrence have proved to be very unsatisfactory and has had a tendency to discourage

the erection of steel head frames in the Butte district.

ANACONDA HEAD FRAME. The steel head frame at the Anaconda Mine of the Anaconda Copper Mining Co., Butte, Montana, was the third steel frame erected in Butte, and the first one erected by the Gillette-Herzog Mfg. Co. This frame is 59 feet high and weighs 74,700 lbs. The dimensions and sections are given in Plate VI. It was designed for ten-ton skips and 7" x ½" steel ropes and was made heavy to suit the Mining Company. This frame is very rigid and has given perfect satisfaction in every way. At 4o cents per hour the shop cost was 1.56 ¢ per pound. The actual cost of erection everything being riveted, was $12.20 per ton.

STEWARD HEAD FRAME. The steel head frame, 55 feet high, at the Steward Mine of W. A. Clark, Butte, Montana, was the first steel frame built for an inclined shaft in Butte. This frame was designed by the Gillette-Herzog Mfg. Co. to take the stresses actually coming on it produced by five ton loaded skips. The dimensions and section are given in Plate VII. The weight of this frame is 45,000 pounds At 40 cents per hour the shop cost was 2.08¢ per pound. The high shop cost was probably due to the amount of lacing and connection plates. The actual cost of erection, everything being riveted, was $15.20 per ton. This frame is doubtless the best designed frame for an inclined shaft in Butte if not in the United States.

BASIN AND BAY STATE HEAD FRAME. The design of the 60 foot frame in Plate VIII. by the writer for the Basin & Bay State Mining Co., Basin, Montana, was made in 1897, just after the erection of the St. Lawrence and West Colusa Head Frames. This frame was designed so that it would break an 1-¼" steel rope without

causing the stresses in the frame to exceed the working unit stresses. The resultant was taken as coinciding with the hoisting rope, as it would in case of overwinding, in place of the usual assumption that it bisects the angle between the hoisting rope and center of the shaft. This assumption made the frame heavier than would now seem necessary. The wind load was taken at 300 lbs. per lineal foot vertical, equally distributed between the two systems of wind bracing. The following working stresses were used: Tension 15,000 lbs. per square inch; compression 13,500-54 $\frac{l}{r}$ lbs. per square inch.

DESIGN OF STEEL HEAD FRAMES. The braced tower type, Fig.1 Plate I is certainly the best type for timber head works. It is easily erected, can be built up for the most part of small timbers, and appears to give a maximum rigidity. This type is well adapted to a steel frame for a quadruple compartment shaft, two shafts coming in front of the others, where it is necessary to hoist from two compartments at once.

The best form for steel head works for deep mines having one or more compartments in a line is the "A" type, shown for vertical shafts in Plates VI and VIII for an inclined shaft in Plate VII. For a vertical shaft the front braces should be vertical in a vertical projection of the side of the frame and the back braces should be at an angle of about 30 degrees with the vertical. The front braces should batter about ½ inch to the foot in a plane at right angles to the side, the back braces having the same spread at the bottom as the front braces.

The hoisting engine is usually placed at a distance from the shaft equal to the height of the sheaves, the rope thus making an angle of about 45 degrees with the horizontal. The friction in

the sheave makes the stress in the rope about 4 per cent more than the stress caused by the loaded ship or cage. The resultant of the stresses in the ropes would bisect the angle between the hoisting rope and the centre of the shaft if it were not for the friction above referred to, and for all ordinary conditions may be so assumed In case of overwinding, or if the skip sticks in the shaft the resultant coincides with the hoisting rope tending to overturn the frame if it is not firmly anchored on the front side.

Crucible steel ropes 1-¼" in diameter are usually used for vertical shafts with 5 ton skips. The breaking load of these ropes is about 41 tons and the safe working loan is about 10 tons. Double compartment shafts usually run balanced, i.e. one skip descends while the other ascends, the weight of the empty skip balancing the weight of the loaded skip, and it is therefore practically impossible to break both ropes at once. The chances that a rope will break before the hoist is stopped or stalled are small, and it would not seem necessary to design a frame for the maximum stresses that might come on it. If we assume that the maximum stress on one side is 60,000 lbs; 22,000 lbs. being transferred to the other side, it would only to seem necessary to design for a maximum stress of 30,000 lbs. in the rope, inasmuch as the working stress is always less than one-half the elastic limit. Under these conditions the stresses in the frame when the rope was broken would be less than the elastic limit. A pull of 30,000 pounds has been used as the maximum pull in the ropes in designing several steel frames and seems to be about the proper amount. For extremely heavy frames the Z-bar column is the best section for posts, but for light frames and tall frames, posts made of two channels back

to back, laced, is the best section. Posts made of two angles have been used, notably in Pennsylvania, and have the advantage of easy connections and shop work, but the section is not an economical one for heavy loads. The 4-angle box column is about the poorest column possible on account of the difficult and eccentric connections and the large percentage of lace bars. Channels laced or battened make good struts. Angle diagonals on the back and front, and channel braces on the sides are preferable. Many frames have been put up which were not properly braced. The cross bracing should be run down to the ground if possible and cross struts should be used at the bottom unless the bases are firmly anchored, in which case no allowance can be made for expansion and contraction due to changes in temperature.

The sheaves should have a diameter of from 75 to 100 times the diameter of the hoisting rope to prevent undue wear on the rope due to bending and should be very carefully set. It would seem to be best to leave an opening in the platform so that the skip could be pulled over the frame in case of overwinding in place of breaking the rope, and thus allowing the skip to drop back into the shaft. This has been done in the case of some of the steel head frames in Pennsylvania, but has not been done on any of the frames built in Montana. The frame should be high enough so that the sheave can make one revolution after the skip passes the landing without striking the landing above. The position of the skip is usually shown by means of an indicator placed in the hoisting room, and it often gets out of repair making it hard to tell the exact location of the skip.

DESIGN OF A STEEL HEAD FRAME. Dimensions:- The head frame will be 63 feet from the base of frame to centre of sheaves. The base will be 25 ft. by 30 ft., and the width at the top 10 ft. The frame is to carry two sheaves 8 ft. in diameter turned for an 1-$\frac{1}{4}$" crucible steel rope properly placed and supported for a double compartment shaft. The compartments are to be 4 ft. 4 in. by 4 ft 4 in. in the clear, with 12 inch wall and division timbers. The hoisting rope will make an angle of 45 degrees with the horizontal.

Capacity:- The frame is to be designed to hoist ore from a shaft 2000 feet deep. The ordinary live load on the 1-$\frac{1}{4}$" steel ropes will be a skip weighing 2000 pounds a load of 10,000 pounds and the weight of the rope when skip is at the bottom of 3000 pounds making 15,000 pounds in all. To allow for sudden stresses due to acceleration, sticking of the skip, etc., this should be multiplied by two which gives a working stress of 30,000 pounds in each rope (this agrees with the working load which should be used with an 1-$\frac{1}{4}$" rope, given above). Each shaft will be considered independent and the frame will be designed for a maximum stress of 30,000 pounds tension in each rope. The weight of the structure will be used in figuring the stresses in the members and will be assumed to be applied at the top equally distributed among the four legs. The wind load will be assumed to be 25 pounds per square foot of vertical projection of the frame, and will be assumed to act horizontally, and normal to the sides in turn.

Material:- The steel shall be that known as medium steel, and shall have an ultimate strength of from 60,000 to 70,000 lbs. per square inch, an elastic limit of not less than one-half the ultimate strength, a minimum elongation of 22 per cent in eight

inches, and shall stand bending 180 degrees around a diameter equal to its own thickness without fracture on the outside of the bent portion. It shall not contain more than .06 per cent sulphur nor more than .08 per cent phosphorous. In other particulars it shall be in accordance with the Manufacturers Standard Specifications

Allowable Stresses:- The allowable tensile stress in posts and braces will be taken at 12,000 lbs. per square inch. The allowable compression in the posts and struts will be given by the formula $12,500-54\frac{l}{r}$ lbs. per square inch. The allowable stress on the extreme fibre for cross-bending in beams will be taken at 12,500 lbs. per square inch. Proper provision must be made in those members having direct and cross-bending stresses.

Workmanship:- The frame is to be built of first-class material in a neat and workmanlike manner. No steel less than ¼ inch shall be used except for fillers. The pitch of rivets shall not exceed 6 inches nor sixteen times the thickness of the thinnest plate nor be less than 3 diameters of the rivets. The rivets shall be 5/8 in. and 3/4 in. in diameter. The distance between the centre of the rivet and the edges of the piece shall not be less than 1-½ in. except in bars less than 2-½ in. wide. Rivet holes shall be so punched that a hot rivet can be entered in the holes after assembling without reaming or drifting. Rivets when driven shall have round heads, concentric with the holes, and shall fill the holes. Loose rivets must be cut out and re-driven. Field riveting must be reduced to a minimum.

Painting:- All iron work before leaving the shop is to receive one coat of oil. After erection the structure is to receive two coats of Graphite Paint.

The head frame is to be erected complete in place in _____ days from date of order on foundations furnished by the mining company. Anchor bolts will be furnished by the steel contractors but will be set by the mining company.

Stresses:- The stresses and sizes are shown on Plate IX.

S T E E L S H A F T H O U S E S.

WAR EAGLE SHAFT HOUSE. The War Eagle Shaft House was designed by the writer for the War Eagle Consolidated Mining and Development Company, Rossland, B.C. in 1898. The shaft is inclined at an angle of 58 degrees with the horizontal and has two compartments. The skips hold 3,000 pounds of ore. The hoisting rope is 1-½" crucible steel. The dimensions and sizes are given on Plates X and XI. The head frame was designed separately, and the building was designed to protect it from storms. The specifications given below which were submitted with the designs will explain the work. This shaft house was erected essentially as designed by the writer by another firm. The estimated weight of this shaft house was 310,000 pounds and the estimated cost erected as per specifications below was $18,500.00.

SPECIFICATIONS FOR STEEL HEAD FRAME, ORE BINS,

AND STEEL SHAFT HOUSE FOR THE WAR EAGLE CONSOLIDATED

MINING AND DEVELOPING COMPANY, ROSSLAND, B.C.

SUBMITTED BY THE GILLETTE-HERZOG MFG. CO.,

MINNEAPOLIS, MINN. U.S.A. M.S.KETCHUM,

AGENT AND ENGINEER.

Items included:- The work shall consist of the following items, namely; one head frame, two ore bins each of 30 tons capacity, one inclined bridge, all necessary grizzles, the ore car floor and sorting floor, the shaft house and timber room, and the hoist house with supporting columns, all constructed in accordance with the general plans submitted herewith, erected in place at Rossland B.C.

Steel Head Frame:- This frame is to be 100 feet high from the foundations to the centre of the sheaves, and is designed for a double compartment shaft which has one 3-ton skip on each side. The sheaves are to be 6 feet in diameter of an approved pattern, the grooves are to be turned for 1-½" ropes. The boxes are to be made adjustable so that the sheaves may be set truly in position. The frame is to be properly braced to sustain wind and dead and live loads that will come upon it.

Steel Ore Bins, Floors, Etc:- These are to include the following: One waste bin and one first-class ore bin, each having a capacity of 30 tons, with one ore gate of an approved pattern in each, one bin having a capacity for 25 tons for coarse ore, and one bin having a capacity of 25 tons for fines, each being supplied with an ore gate of an approved pattern. The moveable gates and the hoppers above the ore bins are to be as shown. The grizzles for the upper 9 x 14 feet are to be spaced 2 inches apart and for the lower 9 x 14 feet are to be spaced 6 inches apart, all being properly supported with necessary framework. The ore car and sorting floors are to be as shown on the accompanying design.

Inclined Bridge:- The inclined bridge is to extend from the mouth of the shaft to the top of the bins and is to be of lattice girder construction, designed for 3-ton skips. The timber for the guides and stringers will be furnished by the owners, but will be erected in place by the steel contractors.

Shaft House:- This building is to be 121 ft. 6 in. long by 33 ft. wide, by 40 ft. high to the eaves, above which a section is continued to cover the Head Frame. The side covering is to be number twenty-four painted iron, having 2-½ inch corrugations; the roof covering is to be number twenty-two painted iron having 2-½ inch corrugations. The roof is to have a lining of asbestos millboard, laid beneath the corrugated iron on wire netting.

Hoist House:- The walls of this building are to be of brick furnished and put in place by the owners. The roof frame is to be of steel and the roof covering is to be as specified for the Shaft House.

Timber Room:- This building is to be 32 ft. by 38 ft with

20 ft. posts. The frame work is to be of steel and the roof and side coverings are to be as specified for the Shaft House.

Windows:- Windows are to be arranged as shown, and are to be furnished by the owners but are to be erected by steel contractors.

Stairs:- Neat steel stairs with wood treads and gas pipe hand rail will be furnished by the steel contractors, to run from the ground floor the the sheave floor as shown.

Material:- The frame work is to be constructed of medium steel. The specifications governing the quality and workmanship are to be standard specifications adopted by the Association of American Bridge Builders as printed in the hand book of the Carnegie Steel Company.

Painting:- All steel work is to receive one coat of mineral paint before leaving the shops and after erecting the entire structure is to receive one additional coat of paint.

Lumber:- All lumber required in the construction, erection, and completion of this work is to be furnished by the owners, but is to be erected by the steel contractors.

Foundations:- All masonry foundations are to be furnished and all anchor bolts are to be set by the owners in accordance with the plans to be furnished by the steel contractors. All anchor bolts will be furnished by the steel contractors promptly so as not to delay the work. It is also understood that the foundations are to be built by the owners so as not to delay the erection.

Freights and Duties:- The steel contractors are to assume all freights to Rossland and are to pay all duties on the material. All switching and cartage charges at Rossland are to be assumed by the owners.

General:- The work is to be executed in a thorough and workmanlike manner. The details must develope the full strength of the construction as nearly as possible, and the whole work must be done in accordance with the accompanying plans and specifications.

BALTIC SHAFT HOUSE. The shaft house shown in Plate XII was designed by the writer for the Baltic Mine, Houghton, Mich. in 1899. The shaft is a double compartment shaft inclined at an angle of 72 degrees with the horizontal. The skips hold 5 tons and run balanced. The centre of the sheave is 70 ft 7 in. above the ground. In order to make room for the grizzles and crushers it was necessary to run the wind bracing down the outside of the roof and building.

The head frame was designed for a tension of 30,000 pounds in each rope. The resultant of the stresses in the ropes falls well within the base of the building. The hoisting rope is an 1-¼" crucible steel rope. Rock was assumed to weigh 90 lbs. per cubic

The loads on the floors were two crushers at 24 tons each, one engine at 5 tons, and grizzles and loose rock at 100 tons. The estimated weight of the structure complete was 256,000 pounds.

CARBON TIPPLE. The Carbon Tipple shown in Plate XIV. designed by Mr. Fitch and the writer was erected by the Gillette-Herzog Mfg. Co. at Carbon, Montana, in 1898 for the Anaconda Copper Mining Co., of Butte, Montana. It consists of a head frame 90 ft. high and a building 41 ft. by 150 ft. with 44 ft. posts, and contains two plate floors.

The total weight was 372,200 pounds or 60.5 pounds per square foot of horizontal projection. The shop cost at 40¢ per hour was $3600.00 or 0.97¢ per pound. The total cost of erection was $1675.00 or $9.00 per ton.

S T E E L M I N E B U I L D I N G S.

EAST HELENA TRANSFORMER AND BLOWER BUILDING. This building was designed by the writer and erected by the Gillette-Herzog Mfg. Co. for the Helena Water and Electric Power Co. at East Helena, Montana, in 1898. The building was designed to contain the transformers for reducing the voltage of the electric current transmitted from Canyon Ferry, a distance of 12 miles, that run the blowers and other machinery for the smelter, and the blowers just referred to. The transformers are quite expensive and are seriously affected by dampness and changes in temperature. This made it necessary to place them in a fire proof building and in a dry building. The building is 60 ft. by 75 ft. with 18 ft. posts. The pitch of the roof is 1/5 (twelve feet at the centre). The dimensions, sizes

and specifications are given on Plate XIII. The Anti-Condensation Roofing is made by stretching ordinary wire poultry netting over the purlins, stretched very tight and carefully woven together on the edges; on this is laid one layer of Asbestos Felt 1/16 in. thick and then the corrugated iron. The Asbestos Felt comes in rolls about 40 inches wide and is laid so that it laps and break joints. Although not usually used a layer of tar paper should be laid on the top of the Asbestos Felt to prevent the water which may find its way through the corrugated iron, from soaking through the asbestos and dripping down on the inside. To prevent sagging stove bolts with 1" x 4" sheet iron washers on the lower side were passed up through the corrugated iron midway between the purlins, and about 2 ft. apart in rows, and were screwed up firmly. The writer would recommend that the purlins be put not to exceed 3 feet apart where Anti-Condensation Roofing is to be used, thus avoiding the use of rivets or bolts which are sure to make leaks in the roof, if the erector is careless and makes the hole for the rivet in the bottom of the corrugation, in the place of the top as he should, and also make a stronger roof. The girts on the sides should also be nearer together than those on this building, where corrugated iron lining is to be used as it is impossible to rivet the sheets together with copper rivets between the girts as is usually done with the outside corrugated iron. The writer sees no reason why 2" x 4" girts without the channels would not be just as good as those shown. There is very little danger from fire by having the wood in the wall, and even if the girts did burn they could not set anything else on fire. This scheme was used in the case of two buildings designed by the writer for the Winona Mine in Michigan and was entirely satisfactory.

In the place of the detail shown for the cornice a 1-$\frac{1}{2}$" x 1-$\frac{1}{2}$" x 3/16" angle and a 2" x 3/16" plate, the writer in erecting the building bolted a 2" x 4" to the angle lugs shown, and nailed the roof and cornice to the wood. This detail is the one used by the writer on similar building designed by him later, and is the one to be recommended.

The sliding doors on this building were what is known as "sandwich" doors made by nailing corrugated iron on both sides of a wooden framework. These doors are to be recommended where iron doors are desired.

Three methods are used in fastening corrugated iron to the purlins and girts: (1) a strip of sheet iron is passed around under the angle or channel purlin or girt and is riveted with a single rivet above and below the member: (2) a 2" x 4" nailing piece is bolted to the upper side of the purlin or girt and the corrugated iron is fastened to these nailing strips with barbed wire nails 2-$\frac{1}{2}$ in. long; (3) wire nails 1/8 in. in diameter and long enough to pass around the purlin or girt, 7 in, to 9 in. long, are driven through the corrugated iron on the upper side and are clinched around the leg of the angle or channel which constitutes the member in question. The first method is the most expensive and the poorest, the second method is the easiest and the best where Anti-Condensation Roofing is used but has the disadvantage of exposing wood where it is desirable that no wood be visible, and is slightly more expensive than the third method. The third method is the most satisfactory under ordinary conditions.

The best column for a building of this type is, without doubt, the four angle column used in this building. It can be made suf-

ficiently deep to take the flexure due to wind, gives easy and simple connections for the knee braces and truss at the top, is light and economical, and lastly is a nice looking post. The angle columns used at the corners in this building are almost ideal corner posts and this has since been adopted by the Gillette-Herzog Mfg. Co. as their standard corner post. This post is heavier than it needs to be, as a 5" x 5" x 3/8" angle would have been amply strong.

In erecting this building the trusses were riveted up on the ground and bolted to the posts. The posts and trusses were then hoisted into place by means of a gin pole and hand crab.

The shipping weight of this building was 77,755 pounds of 17.3 pounds per square foot of floor area. The cost of the material was $1435.57 f.o.b. Minneapolis. The cost for shop labor at 40c/ per hour including draughting was $567.50 or 0.73 ¢ per pound. The actual cost of erection, including transportation was $476.65 or $12.20 per ton. The total cost exclusive of freight was $2478.80 The price received was $2747.00 erected the owners to pay freight from Minneapolis. The profit was $268.20. This contract was taken for completion in 45 days from date of receipt of order, and part of the cost of material is extra for material taken from stock. The building was delivered on time, the drawings having been made and part of the material having been ordered from the mill in the meantime.

The erection of plain corrugated iron is usually estimated at 75c/ per square of 100 square feet. The erection of Anti-Condensation Roofing and double lining is usually estimated at $1.25 per square. The erection of a building of this type is usually

estimated at $10.00 per ton.

ANACONDA COPPER MINING COMPANY COMPRESSOR BUILDING. This building 36 ft. by 80 ft. with 16 ft. posts was designed by the writer and erected by the Gillette-Herzog Mfg. Co. in 1898. The trusses are very heavy. Six inch channels were used for purlins. The posts were 9" I beams, the corner posts were made of two 9" Is and a 4" x 4" x 5/16" angle. The walls were made by building up a two course brick wall between the posts. Steel channel window and door frames were used, and the entire structure was finished up in the most expensive way.

The following data may be of interest. Price erected exclusive of freight was $2000.00. The shipping weight was 50,000 pounds or 17.4 pounds per square foot of floor space. The cost of erection, everything being riveted was $125.00 or $5.00 per ton. The shop cost at 40¢ per hour was $430.00 or 0.88¢ per pound.

BASIN AND BAY STATE SMELTER. The buildings for this smelter consisting of one Reverberatory building 80 ft. by 95 ft. with 12 ft posts and one Furnace Building 90 ft. by 100 ft. with 20 ft. posts, together with furnace castings, hoppers, etc. were partly designed by the writer who closed the contract for the Gillette-Herzog Mfg. Co. in 1898. The following data may be of interest. Total weight was 570,000 pounds. Total shop cost at 40¢ per hour including draughting was $5155.00 or 0.90¢ per pound. Actual cost of erection was $9.40 per ton.

Plate I.

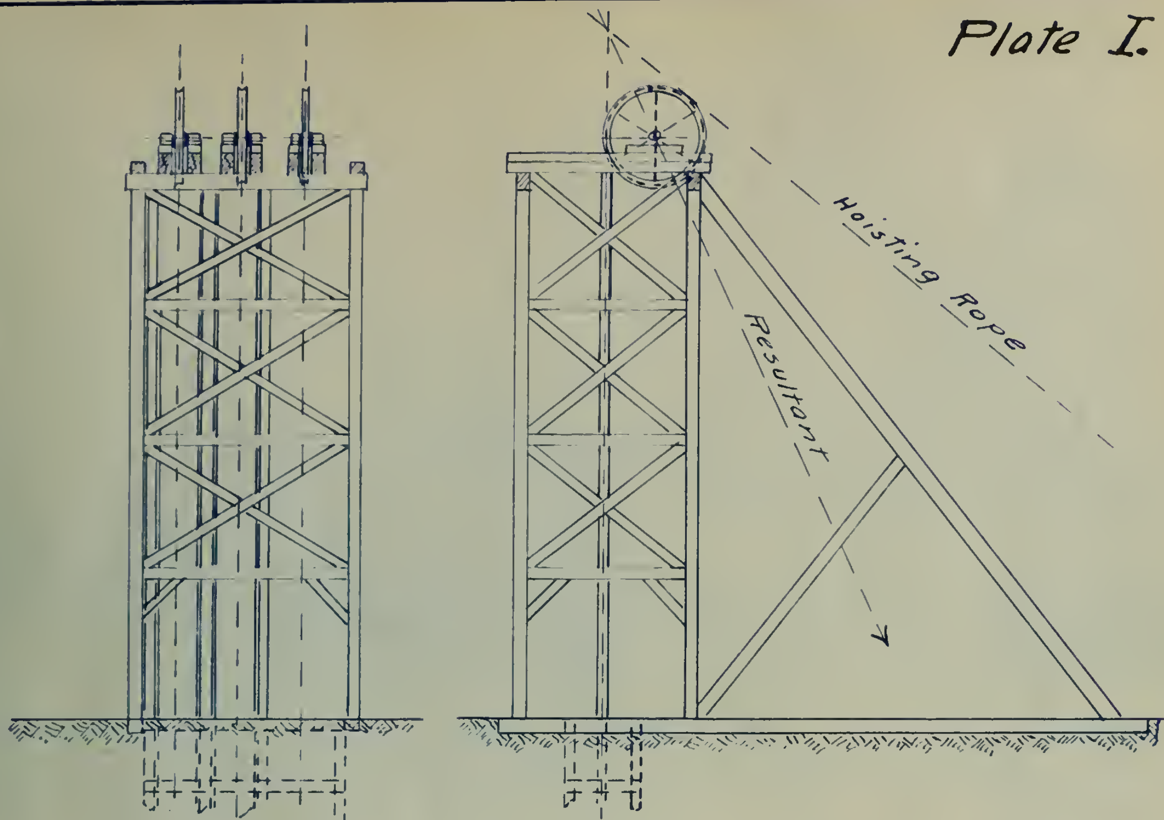


Fig 1 — Timber Head Frame used in South Africa

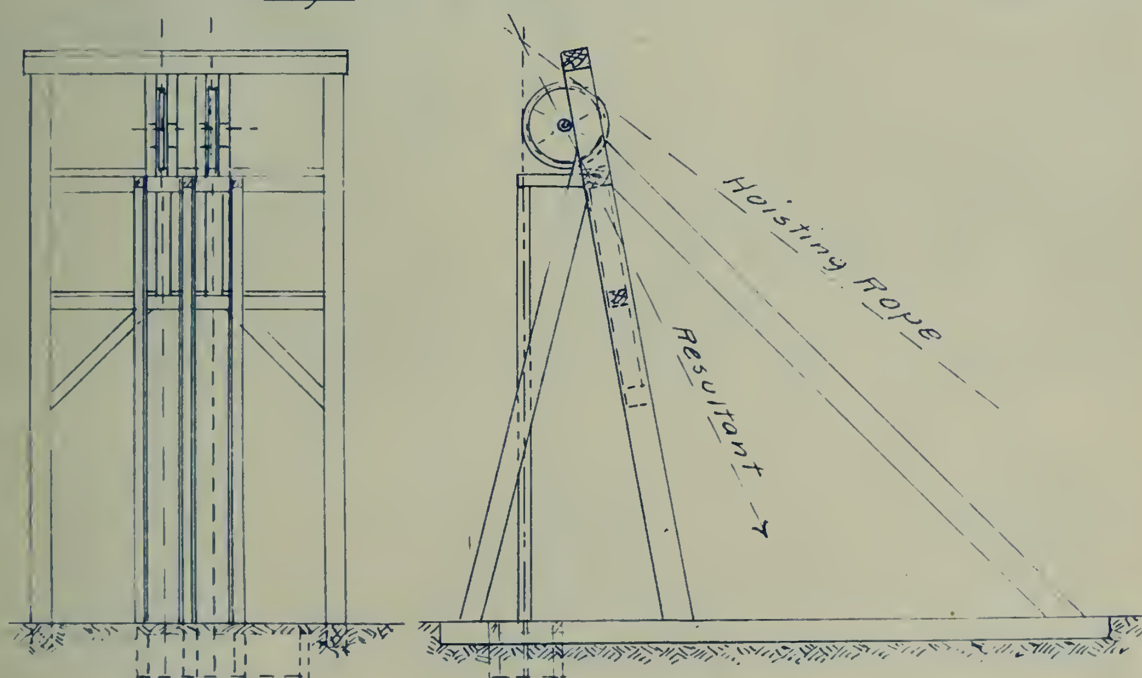


Fig 2 - Timber Head Frame used in Montana.

Plate II.

Plate III

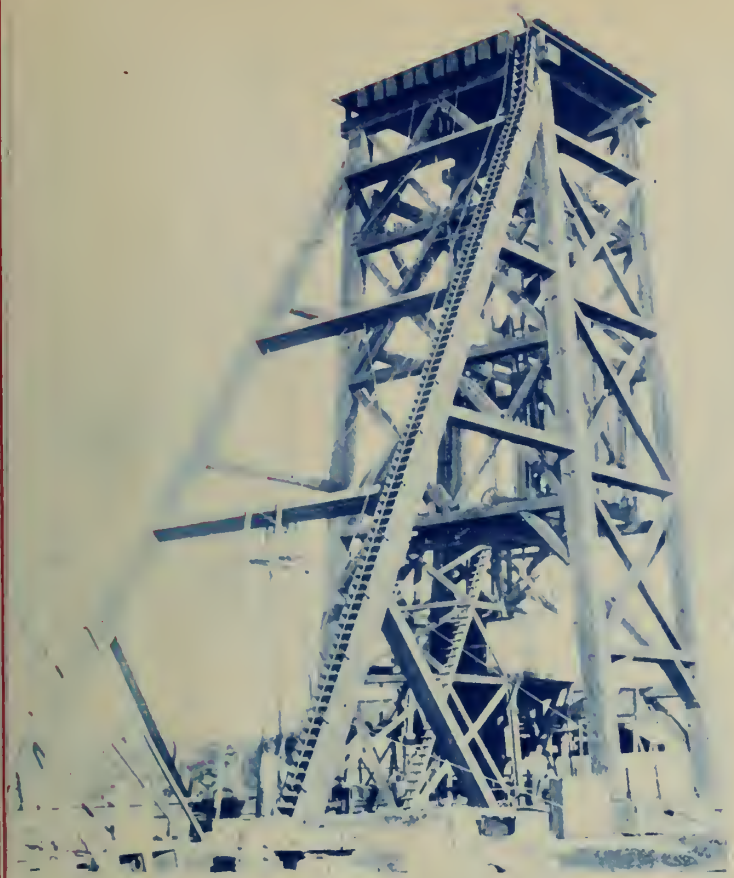


Fig. 2 - Timber Head Frame - South Africa.

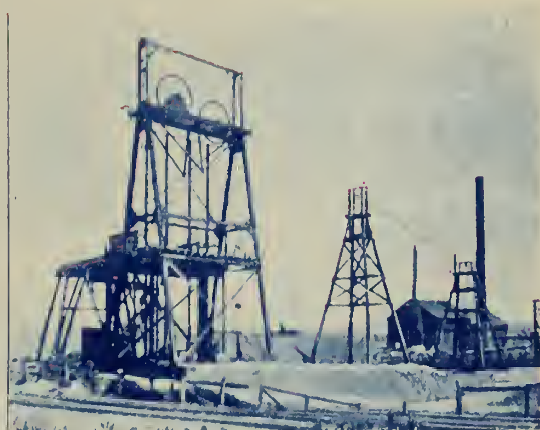


Fig 3 - Aurora Head Frame. Ironwood, Michigan.

Fig. 1. Steel Head Frame - 85 ft high - Robinson Deep Mine, South Africa.

Plate IV

Fig 1.-Gilberton Head Frame.

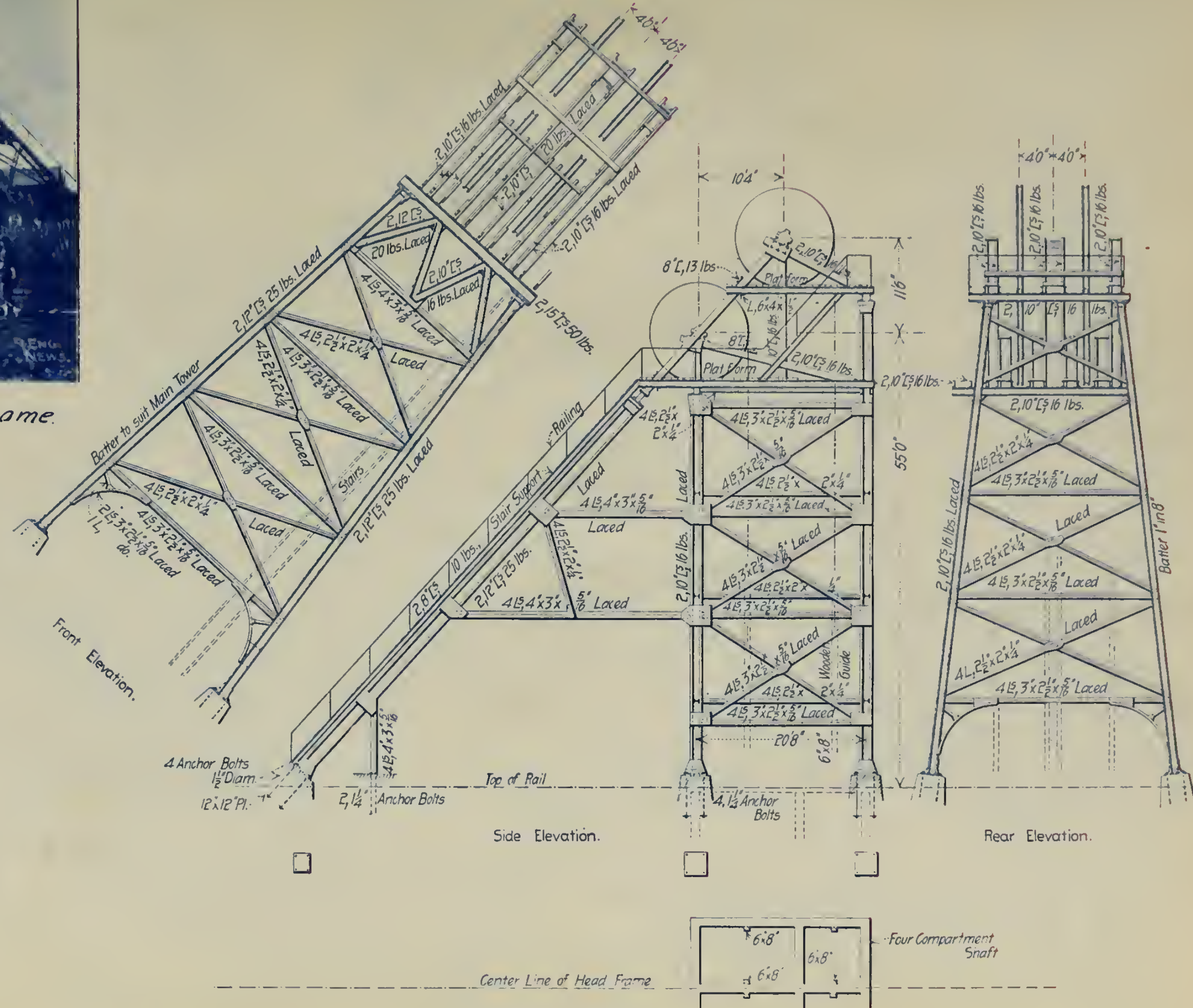


FIG. 2. ELEVATION OF STEEL HEAD FRAME FOR THE PHILADELPHIA & READING COAL AND IRON MINES, AT GILBERTON, PA.
Pottsville Iron & Steel Co., Builders.

Plate V.

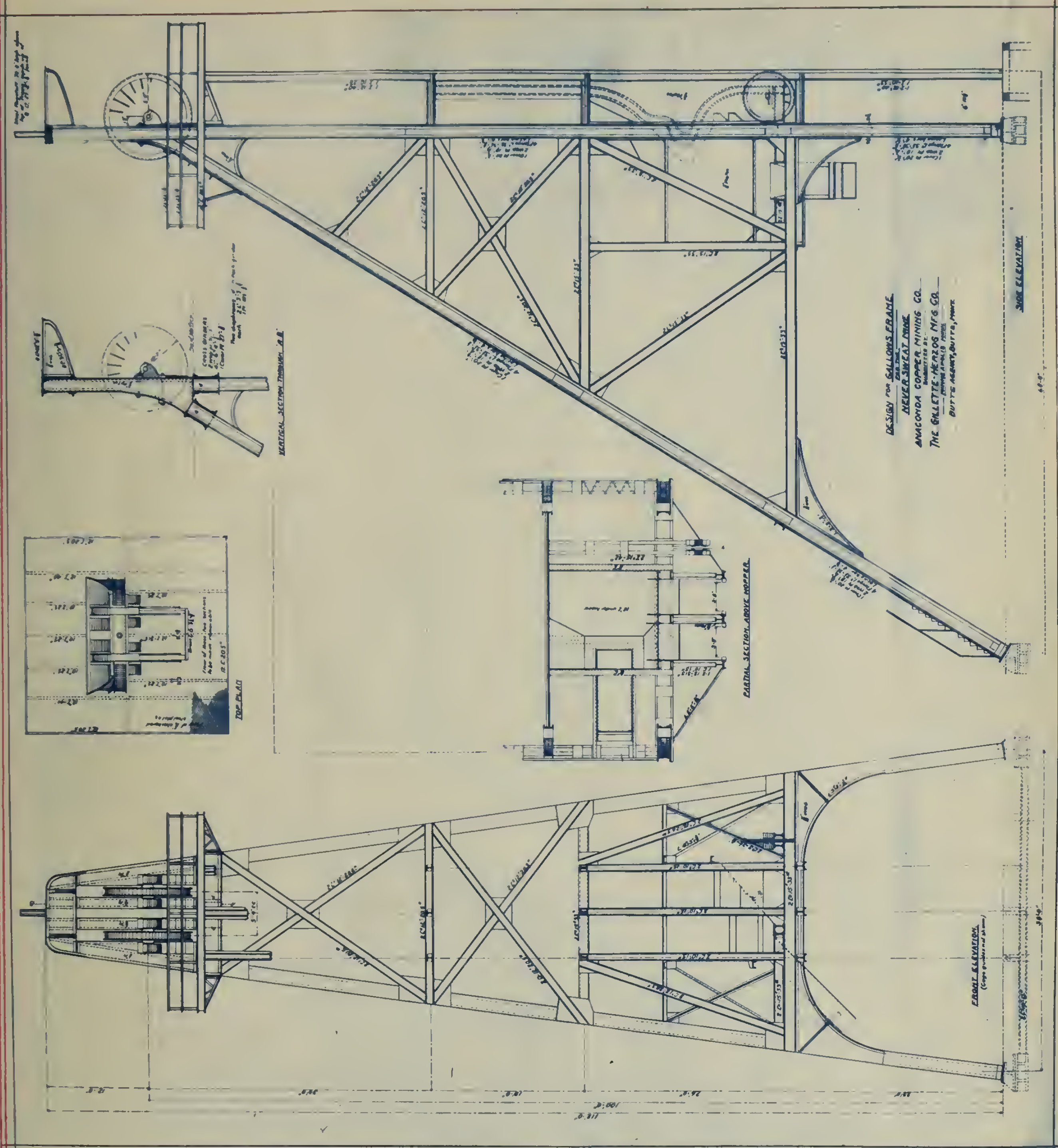

DESIGN FOR GALLOWS FRAME
FOR THE
NEVERSWEAT MINE
ANACONDA COPPER MINING CO.
SUBMITTED BY
THE GILLETTE-HERZOG MFG CO.
MINNEAPOLIS MINN.
BUTTE AGENCY, BUTTE, MONT.
SIDE ELEVATION
VERTICAL SECTION THROUGH A-B
TOP PLAN
PARTIAL SECTION ABOVE HOPPER
FRONT ELEVATION

Plate VI

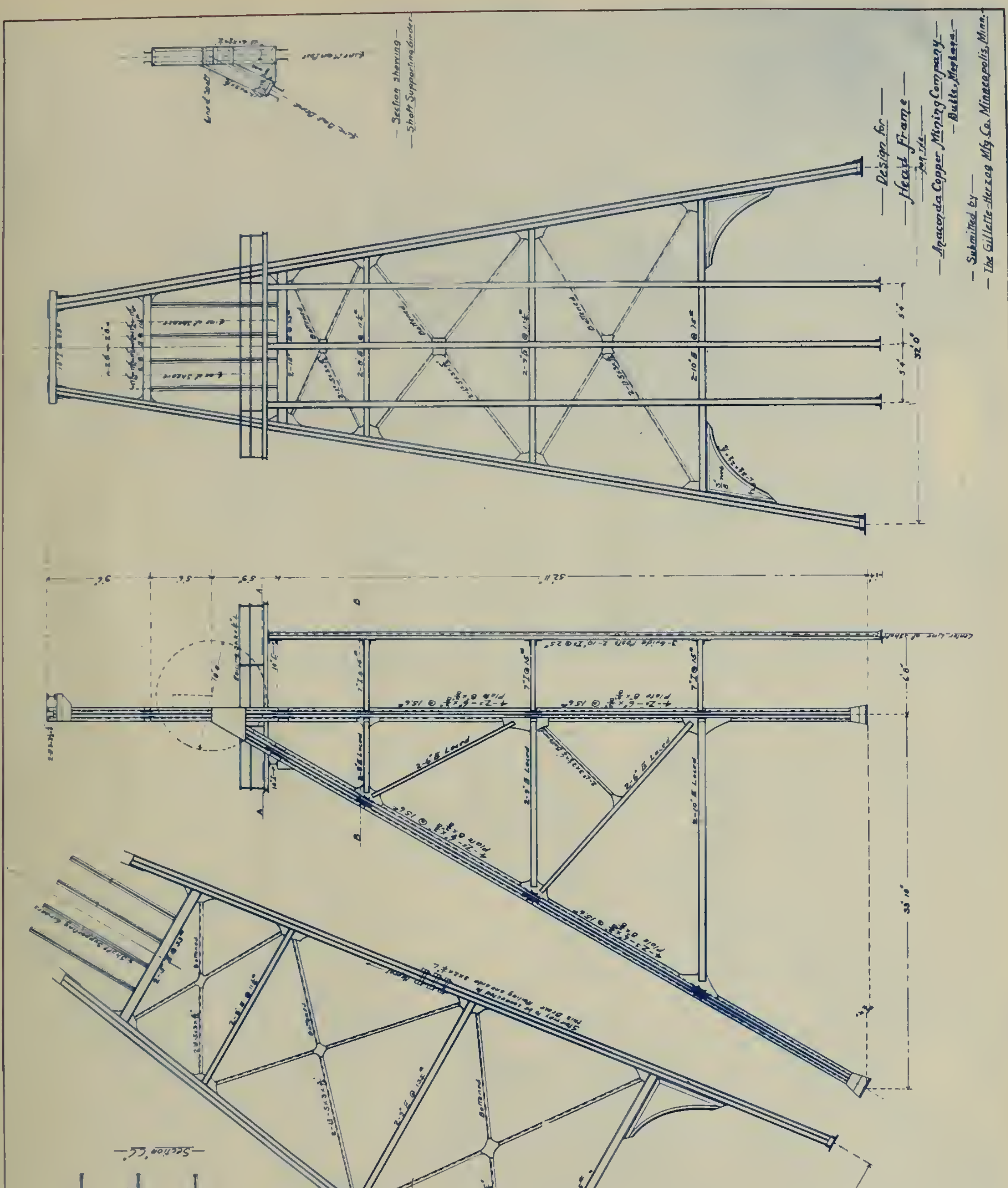
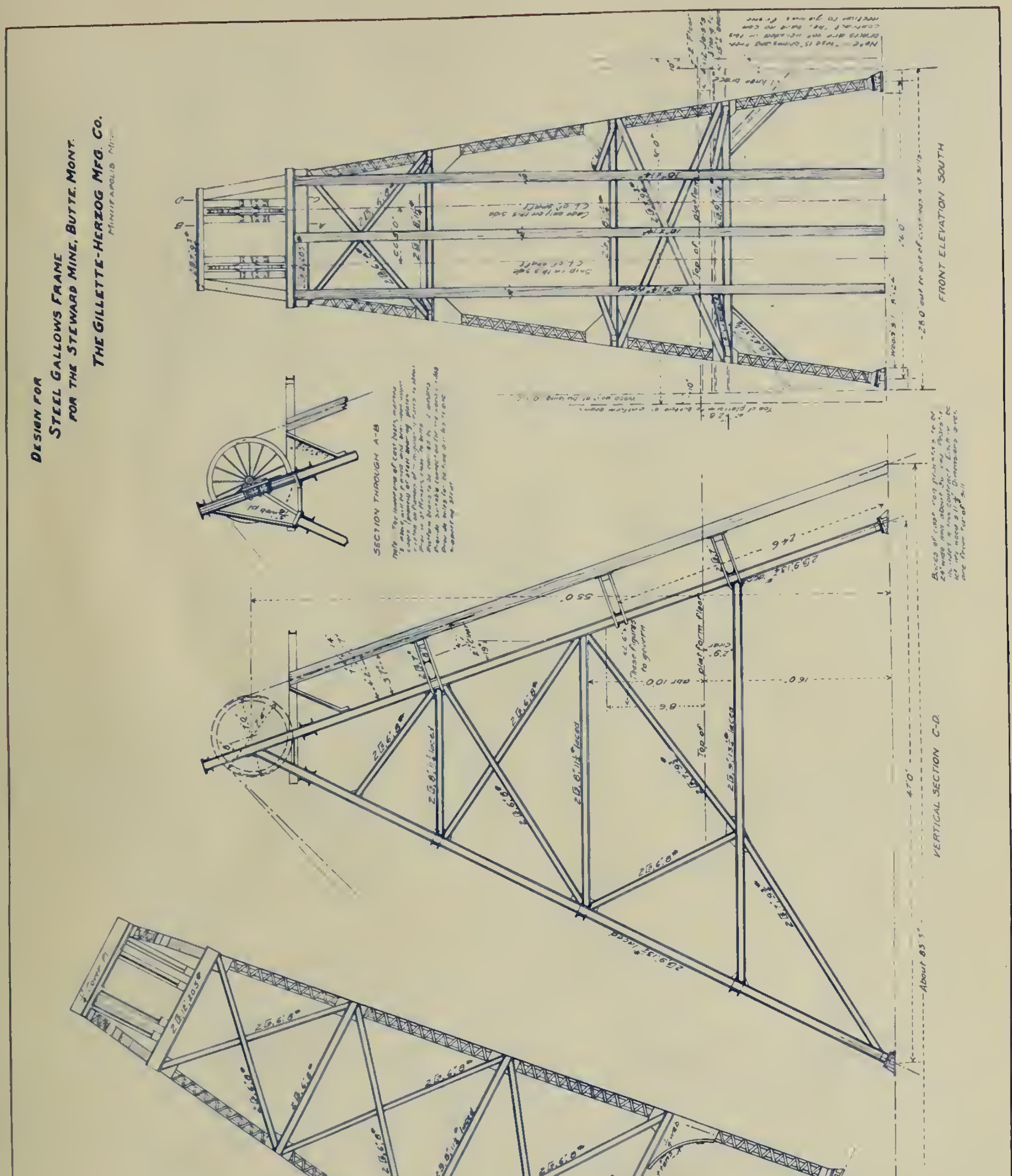
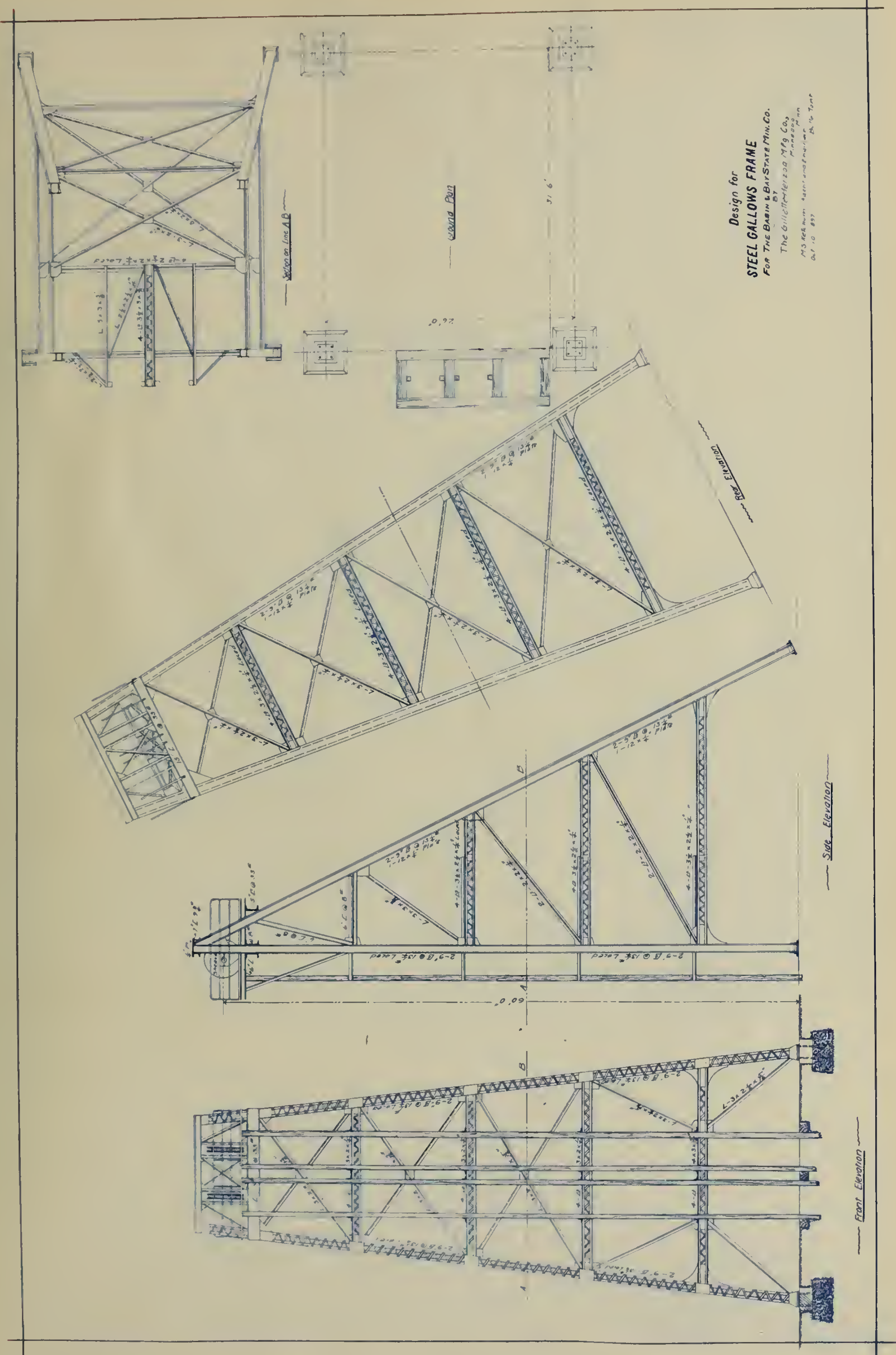

Design for
Head Frame
Anaconda Copper Mining Company
Butte, Montana
Submitted by
The Gillette-Herzog Mfg. Co. Minneapolis, Minn.
Section showing Shaft Supporting Girder
Section "C.C."
Section "B.B."

Plate VII.



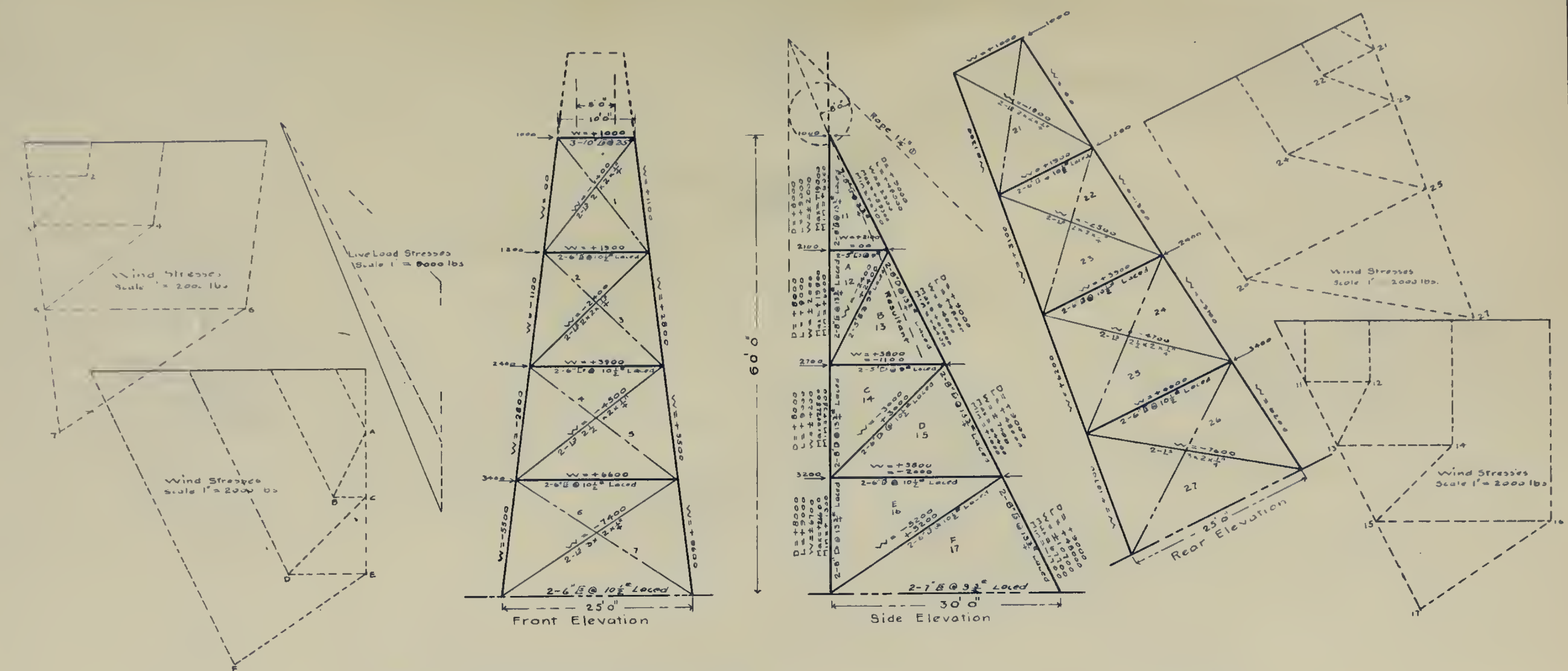
Design for
Steel Gallows Frame
for the Steward Mine, Butte, Mont.
The Gillette-Herzog Mfg. Co.
Minneapolis Minn.
Section through A-B
Front Elevation South
Vertical Section C-D
Rear View

Plate VIII



Design for
STEEL GALLOWS FRAME
For The Basin & Bay State Min. Co.
By
Section on Line A B
Ground Plan
Rear Elevation
Side Elevation
Front Elevation

Plate IX



Specifications:—

Material — Medium Steel, 60000 to 70000 lbs per sq. in., elastic limit not less than one half the ultimate, elongation of 22 per cent in 8 ins; phosphorous not to exceed 0.08 per cent. In other particulars in accordance with Manf'g Std Specifications for material and workmanship.

Dead Load — 8000 lbs vertical on each post

Live Load — 30000 lbs on each $1\frac{1}{4}$" rope.

Wind Load — 20 lbs per sq ft horizontal on the vertical projection of the Head Frame

Tension — 12500 lbs per sq in

Compression — $13500 - 54\frac{l}{r}$ lbs per sq in

Sheaves — 2 - 8' 0" diam tufted for $1\frac{1}{4}$" rope

Field connections to be riveted; paint one coat of oil in shop and two coats Graphite paint after erection. Foundations to be furnished by owners; steel contractor to furnish Head Frame erected complete in place

Rivets $\frac{5}{8}$" and $\frac{3}{4}$" in diam

— Design of —

— Steel Head Frame —

— For a Vertical Shaft —

— By M.S. Ketchum —

University of Illinois.
Champaign, Ill   May 11, 1900

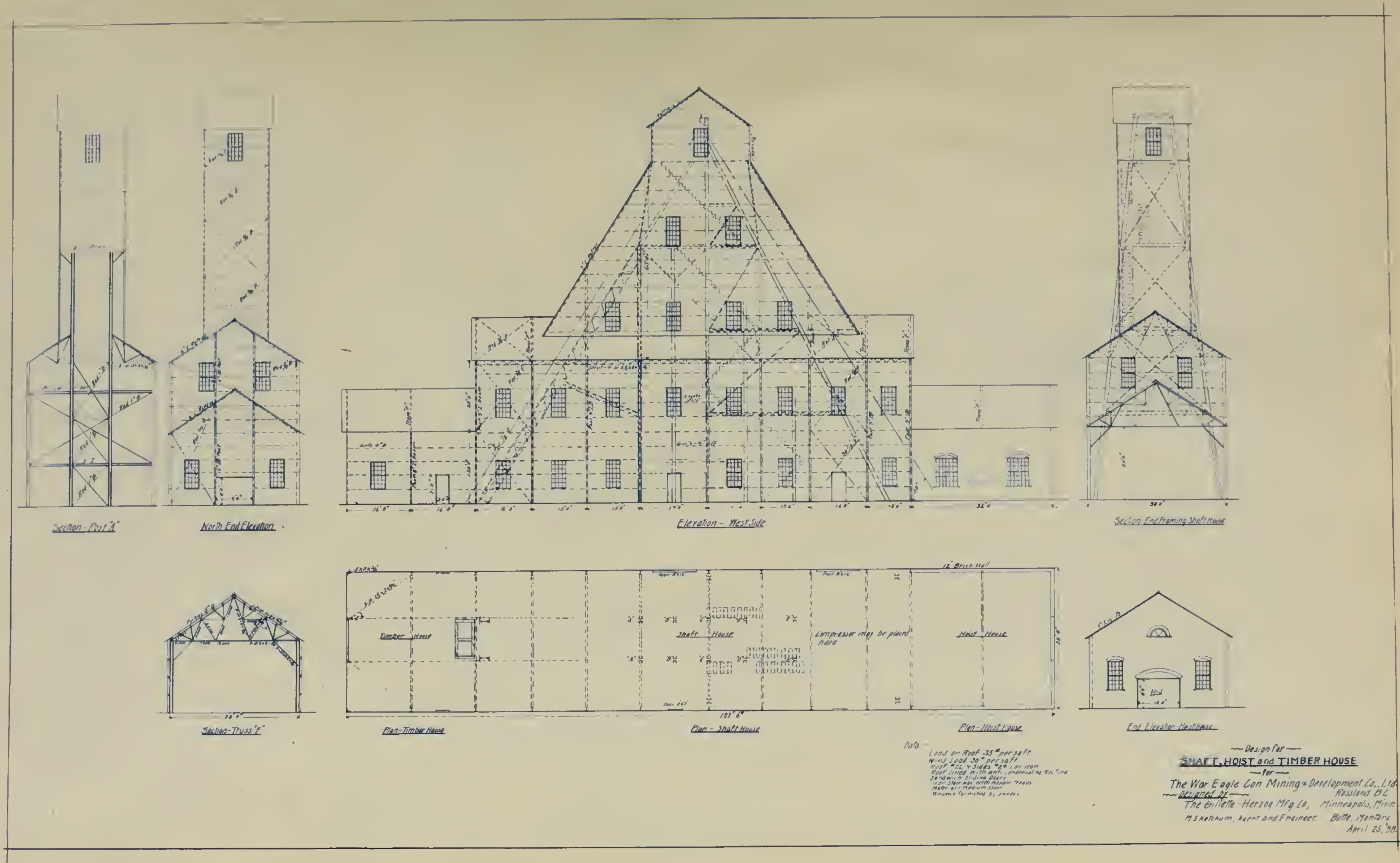
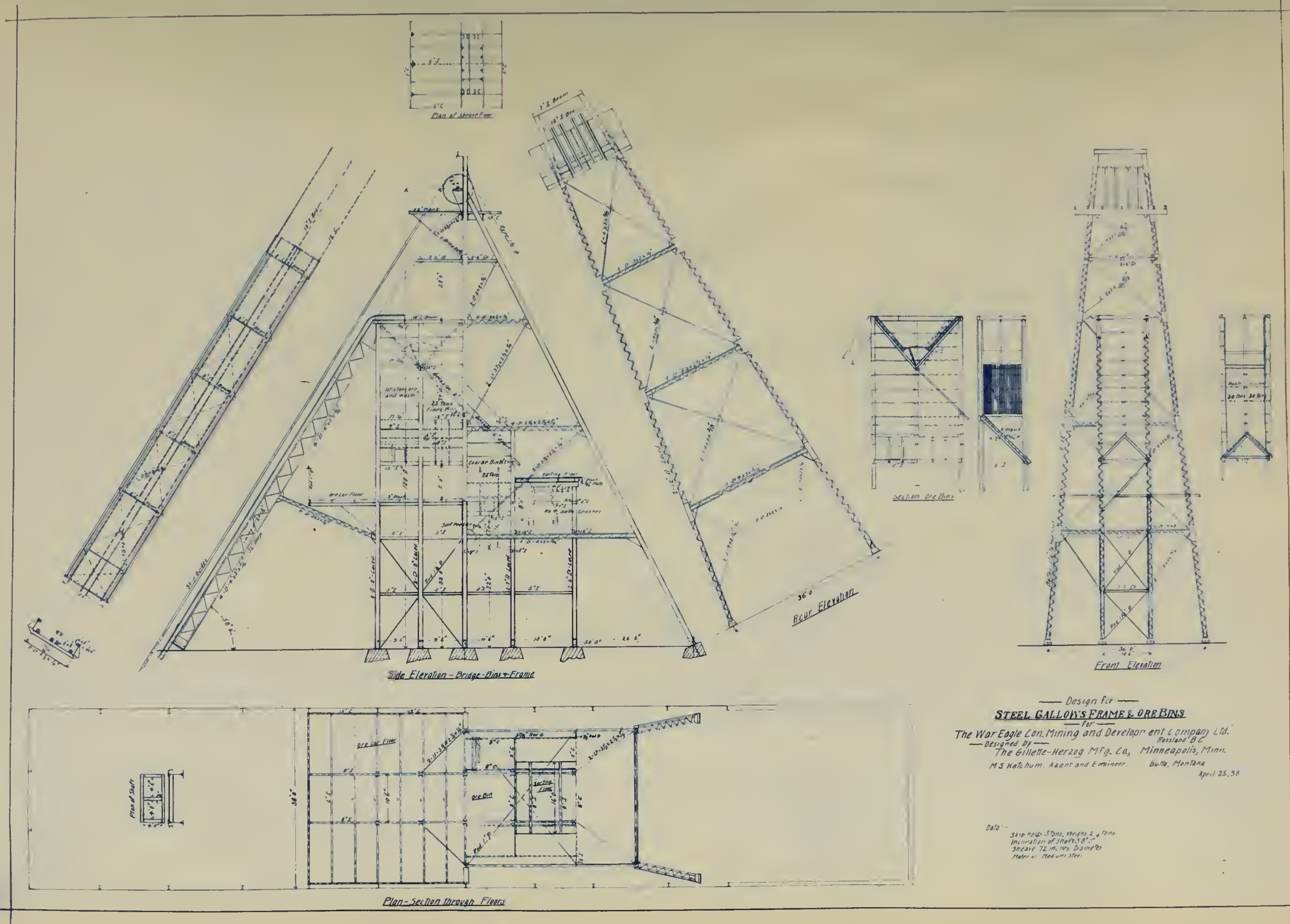

Section - Post "A"
North End Elevation
Elevation - West Side
Section End Framing Shaft House
Section - Truss "F"
Plan - Timber House
Plan - Shaft House
Plan - Hoist House
End Elevation - Hoist House
Timber House
Shaft House
Compressor may be placed here
Hoist House
12" Brick Wall
Data —
Load on Roof 35# per sq ft
Wind Load 30# per sq ft
Sandwich Sliding Doors
— Design for —
SHAFT, HOIST and TIMBER HOUSE
— for —
The War Eagle Con Mining & Development Co., Ltd
Rossland B.C.
— Designed by —
The Gillette-Herzog Mfg Co, Minneapolis, Minn
M S Ketchum, Agent and Engineer. Butte, Montana
April 25, '98

Plate X

Plate XI.


Plan of Sheave Floor
Side Elevation - Bridge - Bins + Frame
Rear Elevation
Section Ore Bins
Front Elevation
Plan of Shaft
Ore Car Floor
Ore Bin
Sorting Floor
Plan - Section through Floors
— Design for —
STEEL GALLOWS FRAME & ORE BINS
— for —
The War Eagle Con. Mining and Development Company Ltd.
Rossland B.C.
— Designed by —
The Gillette-Herzog Mfg. Co, Minneapolis, Minn.
M S Ketchum. Agent and Engineer. Butte, Montana
April 25, 98
Data: —
Skip holds 3 Tons, weighs 2 ¼ Tons
Inclination of Shaft 58°
Sheave 72 inches Diameter
Material Medium Steel

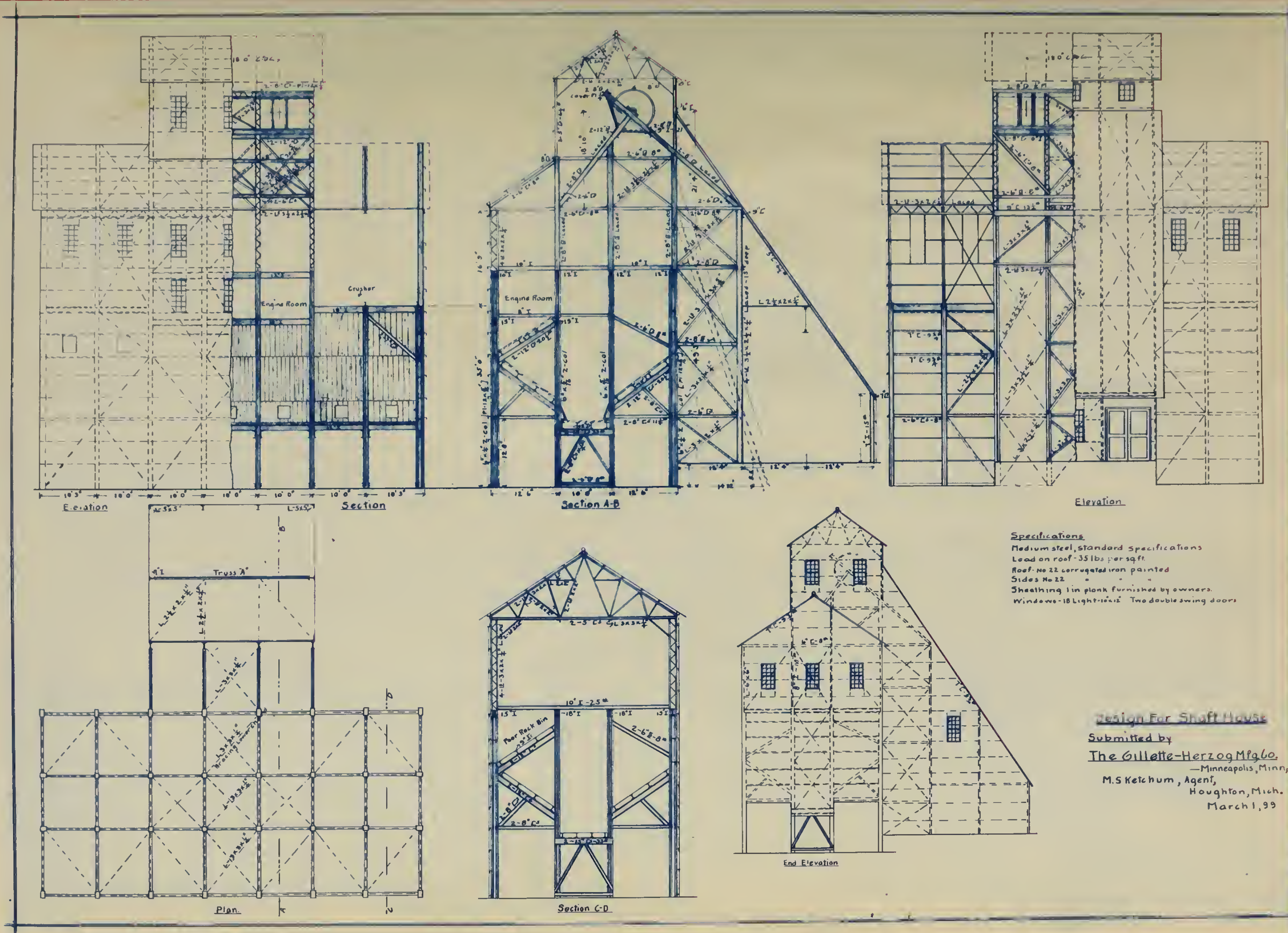
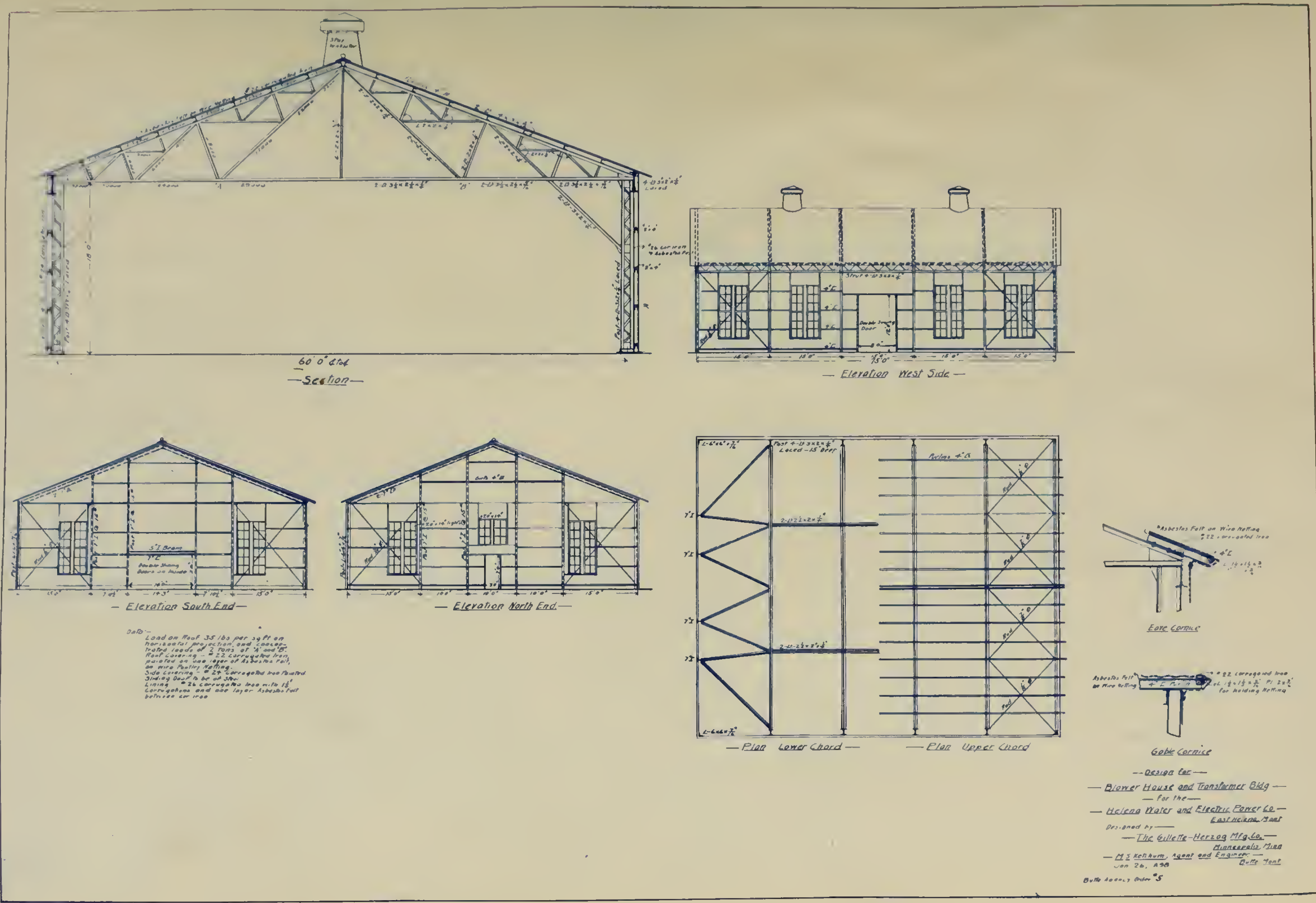

Elevation
Section
Engine Room
Crusher
Section A-B
Engine Room
Elevation
Plan
Truss "A"
Section C-D
Poor Rock Bin
End Elevation
Specifications
Medium steel, standard specifications
Load on roof - 35 lbs per sq ft.
Roof - No 22 corrugated iron painted
Sides No 22 " " "
Sheathing 1 in plank furnished by owners.
Windows - 18 Light-10x12 Two double swing doors
Design For Shaft House
Submitted by
The Gillette-Herzog Mfg Co.
—Minneapolis, Minn.
M.S Ketchum, Agent,
Houghton, Mich.
March 1, 99

Plate XII

Plate XIII



— Section —
60' 0" c to c
— Elevation West Side —
— Elevation South End —
— Elevation North End —
— Plan Lower Chord —
— Plan Upper Chord —
Eave Cornice
Gable Cornice
Data —
Load on Roof 35 lbs per sq ft on horizontal projection, and concentrated loads of 2 tons at 'A' and 'B'.
Roof Covering — #22 Corrugated Iron, painted on one layer of Asbestos Felt, on wire Poultry Netting.
Side Covering — #24 Corrugated Iron Painted
Sliding Door to be of Steel
Lining #26 corrugated iron with 1¼" Corrugations and one layer Asbestos Felt between cor iron
— Design for —
— Blower House and Transformer Bldg —
— for the —
— Helena Water and Electric Power Co —
East Helena, Mont
Designed by —
— The Gillette-Herzog Mfg. Co. —
Minneapolis, Minn
— M S Ketchum, Agent and Engineer —
Butte Mont
Jan 26, 1898
Butte Agency Order #5