REVIEW

OF THE

DESIGN OF THE SYSTEM COLLECTIVE

OF THE

HIGH SERVICE

WATER WORKS

AT

CARMANSVILLE

NEW YORK CITY

L. L. BUCK

1868

INTRODUCTION

No element with which the engineer has to operate, furnishes a more diversified and interesting subject of study than water. The necessity which it satisfies is best measured by its abundance. Yet abundant as it is and though it has been the subject of countless experiments, perhaps no element more completely tests the skill of the engineer and causes him to dread its power, than water. Gravity causes it to seek the lowest point of the earths surface and if we attempt to arrest the progress of even the most gentle stream, we are rewarded only by seeing the water rise, gathering strength every instant and ever seeking the least flaw or crevice until our work is swept from before our eyes. Faithful workmanship but increases the destruction.

It is only in the works of the Creator, where the most perfect adaptation of laws with reference to matter occurs, and where there is the grandest system of compensation, that the action of water does not involve the ultimate destruction of whatever impedes its course.

Nevertheless, man may so construct his works if he make a faithful use of the advantages that are given him, as to make them sufficiently enduring to meet the necessity which they were intended to satisfy.

We are ever longing for change and it is, perhaps, well that art can produce little which shall long outlast the mind which conceived it.

Upon the subject of waterworks much has been said and written. Although full of interest, nothing but a brief sketch of some of the more prominent steps of their progress is admissible in this place.

The wants of man in the primitive ages were few. He was satisfied to quench his thirst from a clear spring or mountain stream by the side of which he erected his simple habitation and lived with little excite his envy or arouse his ambition.

But as population increased and communites were established, necessity compelled other means of supplying water. It was then that the first step was taken, resulting in structures which, though rude, were satisfactory for the time.

The first class of waterworks would, naturally, be that in which the water was taken from a source sufficiently elevated to admit of its being conducted through canals or other conduits to its destination by the action of gravity. Of this class were the waterworks of India and if we are to judge by the evidences which still exist in such profusion, that the traveler, its is said, is astonished on beholding them; that country was, if not first, among the first to adopt extensive artificial systems to supply its inhabitants with pure water.

The second class of waterworks, consisted of elevated reservoirs, into which the water was forced or raised by artificial means from a source less elevated. Such have only been used, where the difficulty of obtaining a supply by the first means, rendered that system to expensive.

It appears that the first machines for raising water were invented in Egypt, under the reign of the Ptolemies. The principles of their construction, were, in many respects, so similar to some of those in use, at the present day, as to lead many to suppose that but little progress has been made since. But this discouraging view vanishes whe we consider that those principles were elementary, and that probably ages were necessary for their developement, perhaps as long a time elapsed, as that which intervened from their invention to the invention of the steam engine, and its application to raising water, which was comparatively recent and which is certainly a grand stride in advance of the hand swape and treadmill systems of those times, while in style of finish and smoothness of action, our machines are greatly superior.

Such inventions only are made by a people as their necessities demand, and the low level lands of Egypt, for a great part of the year without rain, compelled the people to give their attention to devising means for irrigation.

Of the more modern works those of France and Spain furnish examples of both classes.

Still later the English people turned their attention in this direction and in the struggle, which was necessary in surmounting natural obstacles, many of their best engineers were brought out.

Lastly many of the cities of the United States have been compelled to erect waterworks to supply the rapidly increasing demand. Among these are the waterworks of Chicago and of Philadelphia which are "high service". Those of Philadelphia (the Fairmount works take their water from the Scuylkill River and it is raised, into distributing reservoirs, by pumps driven by turbine water wheels.

The Croton Waterworks supplying New York City is an example of low service works. The water is conducted from Croton valley through a brick aqueduct over a distance of about forty miles to they city, crossing the Haarlaem River upon a stone arch bridge, at an elevation, above low tide, of 120 feet and consequently supplies all portions of the city having a less elevation.

The highest portion of the island has an elevation 271½ feet. As the higher portions are, rapidly becoming populated. it has become necessary to construct high service waterworks. The object of this thesis is to review their design and progress of construction. They are denominated the High Service Carmansville Water-Works.

GENERAL DESCRIPTION

The high service waterworks at Carmansville is a branch of the Croton waterworks of which Mr. A.W. Craven was chief engineer to within a late date.

Their construction was commenced in the Spring of 1866, under the direction of Mr. W. L. Dearborn consulting engineer. They are located on the east side of the island at the end of High Bridge. They consist of:

Reservoir. This is situated on the high ground between Ninth and Tenth Avenues and One hundred seventy second and one hundred and seventy fourth Streets.

It is to be of earth enveloping an embankment of clay puddle; the bottom of the reservoir to have an elevation of 205 feet above low tide in Harlaem River, to have a maximum depth of 16 feet of water and to be 276 feet square at the foot of the interior slope, which is 1.5 feet horizontal to 1 foot vertical. In the middle of the east side is to be the

Influent Gate House. It is through this that the water passes into the reservoir

Effluent Gate House. This is to be situated in the middle of the west embankment and through it the water is taken out for distribution.

The first named gate house is to communicate with Croton Aqueduct by means of a sewer for the purpose of carrying off surplus water and for draining the reservoir when required.

The capacity of the reservoir is to be 10.794.178 gallons and is to supply all parts of the city having elevations between 120 and 210 feet above low tide.

Tank Tower. This is to be built of stone and iron. It is to stand near the north east corner of the reservoir, its foundation having an elevation of 205 feet above low tide. It is to support a wrought iron tank 22 feet in depth and 21'6" diameter. The bottom of the tank is to have an elevation of 316 feet above low tide. Maximum depth of water in the tank is to be 20 feet giving a capacity of 49.368 gallons. From the tank will pass a 6 inch cast iron pipe, terminating at a fountain in the center of the reservoir. The tower will have a lookout at an elevation of 363 feet above low tide.

From the tank water is to be taken to supply all that portion of the city, consisting of about 150 acres, having an elevation of more than 210 feet, the highest point being 271.5 feet.

Engine and Boiler Houses. These are to stand at the end of High Bridge. They will be of stone with slate covered roofing. The dimensions are to be such as to accommodate two pumping engines.

Pumping Engines. There are to be two direct acting pumping engines, each capable of raising 2100000 gallons in 10 hours, for the the purpose of supplying the reservoir and tank. But one however is to be built at present and that is to have an air pump and water pump for suplying the towers combined.

The water for supplying the pumps is to be taken from Croton Aqueduct near the gate house at west end of High Bridge.

Inclined Plane. There is to be an inclined plane erected with its lower end directly in front of a coal shed, on a dock by the river. The upper end of the inclined plane is to be at the entrance to the boiler room. Its object is to elevate fuel for the furnaces.

DESCRIPTION OF PARTS

Reservoir.

Bed of Foundation. This is prepared by removing earth down to solid rock. The rock is then blasted away till a surface is found free from fissures, when it is washed clean and a ridge of concrete laid upon it extending quite arround the reservoir and its axis corresponds with the middle line of the puddle wall at the same height. Its cross section is rectangular 4 feet in depth by 2 feet in thickness. Its object is to prevent water, that may chance to trickle beneath the puddle, from escaping to the exterior portion of the embankment.

Puddle Bank. The puddle bank consists of 2 parts clay to 1 part of earth, thoroughly mixed and free from stones or soil. A layer of four or five inches in thickness is laid down and each layer is well chopped through with the spade so as to unite them thoroughly. From the base to the bottom of the reservoir the puddle has a thickness of 10 feet. From that point to the top, a height of 16 feet, the sides have such a batter as to make the top 4 feet thick. Its top is a very little above the free surface of the water in the reservoir at its maximum height.

Earth Embankment. The materials used in constructing the earth embankment is loam free from stones larger than 2" diameter and from vegetable mould. It is built simultaneously with the puddle and in layers of the same thickness each lay being well rammed. It thus serves as a mould for the puddle.

The interior of the bank has a slope of 1.5 horizontal to 1 vertical. It is protected by a slope wall of rubble masonry 18" thick and laid in hydraulic cement. The upper edge of the slope wall is level with the free surface of the water in the reservoir.

The exterior slope of the embankment is 1.75 horizontal to 1 vertical and is covered with 10" thickness of soil. From the upper edge of outer slope to upper edge of inner slope is 11 feet. Next the top of the slope wall is a trench 2 feet wide by 2 feet in depth and filled with concrete to serve as a foundation for.

Parapet. The parapet is of stone, is rectangular in section, 2 ft thick by 2 feet in height surmounted by a cut granite coping 1 foot thick by 3 feet in width, projecting over the vertical faces of the parapet, 6 inches. Outside the parapet is a gravel walk 8 feet in width. 6 inches depth of gravel and its upper surface level with the bottom of the coping.

Steps. The gravel walk is reached by a flight of stone steps (granite) 18 in number.

Effluent Gate House. This rests upon a rock foundation prepared by covering the rock over with concrete to a level with the bottom of the reservoir.

The dimensions are, plan 36 feet by 27 feet and height above bottom of reservoir 20 feet. The exterior walls are of gneis 16 inches thick. Interior walls of brick 12 inches thick. In the end toward the center of the reservoir are two arched waterchambers each 9 feet 6 inches by 6 feet in plan. These chambers have in their side walls, directly opposite to each other, two vertical groves cut 4 in. by 4 in. in cross section for the reception of stop planks in cases of necessity. Just back of these chambers are two other water chambers 5'6" by 6' connected with the former by a passage way 6 feet high 3 ft wide. The bottom of the passage way is raised 1 foot above the bottom of the reservoir for the purpose of keeping out sand &c. In the bottom of the latter chambers are orifices, one in each chamber connecting with a 3 feet diameter sewer, that they may be completely drained when necessary. From each one of these chambers the water is taken out for distribution through a 3 feet diameter cast iron pipe whose bottom is one foot above the bottom of the chamber, to prevent any dirt which may have got in to the chamber from being conveyed into the pipes. The pipes pass, then, through a single large chamber 17 feet by 8 feet in plan. Here they are provided with gates or stop cocks operated by suitable contrivances when it is require to open or close the communication. They are also each provided with a 6 inch pipe connecting them with the before mentioned sewer pipe. The 6" pipes have, each, a stop cock to be kept closed ordinarily. The gate chamber is fitted with an iron open work grillage or floor, for men to stand upon when working the gates. It is reached by steps both above and below. Back of the chamber is a recess 17 feet square in plan and covered with a brick arch for supporting the embankment and puddle which pass over it.

On each side of the gate house is a wing wall having its face a prolongation of the face of the gate house, its top having the same slope as the embankment and supporting an embankment at right angles to the main embankment and fitted with a slope wall. The wing walls are stepped at the back to form a more perfect bond with the dirt and as security against filtration, which would destroy the work.

The stone work is rock faced, laid in hydraulic cement, as uncoursed rubble. joints to be well pointed and joint faces to be hammer dressed so as lay 3/8 of an inch joint.

All spaces within the gate house, except those mentioned above, are to be filled with concrete.

The top of the gate house is to be surmounted by a granite coping 1 foot thick and projecting 4 inches beyond the faces of the wall all around except the side next the embankment where it is to be "flush". There are to be openings through the coping over the chambers where its edges will be flush with the chamber walls.

Influent Gate House. This to be constructed the same as the other, as regards material and workmanship. Its arrangement differs, only, in the following particulars, from that of the former. There is to be but one water chamber 9 feet 6 inches by 8 ft 6 inches, opening through an arched way into the reservoir. By the side of this and having it bottom elevated 15 feet above the bottom of the reservoir is an opening to serve as a waste weir for surplus water. It is fitted with a sluice board which determines the height of the water in the reservoir. Within the gate house and at the back end of this opening is a well communicating with a 3 foot sewer through which the surplus water is carried away to the Croton Aqueduct.

Water enters the water chamber through two 20 inch mains, the bottoms of these mains being 15 feet above the level of the bottom of the reservoir. These pipes have bell mouths and at the end, they are 3 ft diameter, the curve of their section convex inward and having a radius of 75 feet.

From the bottom of the water chamber a three foot sewer passes out through the embankment forming a junction with the sewer mentioned above.

Back of the water chamber is a gate chamber 17 feet by 8 feet in plan.

The plan of the gate house is 27 feet by 27 feet 6".

Tank Tower

Bed of Foundation. This is prepared by leveling off the solid rock at the elevation of 196' 6" L.S.

Foundation. The foundation consists of a wall of gneis masonry 6 feet 4 inches thick and 2 feet 6 inches high. The whole of the space within this wall is filled with concrete to a level with the top of the wall.

Lower story. This to be octagonal in plan and 29 feet outside diameter, 22 feet 4 inches high. Walls to be built of dark Quincey granite and best New York island Gneis. Granite to be outside and to have beds of 28 inches. the rise of the courses to be 15 3/4 inches excep the lower course which is to be 2 feet 6 inches. all joints full throughout and to have the beds dressed so as to lay 1/4 inch thick; the stone to have a good quarry face free from drill marks. The granite and gneis to be well bonded with headers 2 feet 6 inches long. The stone masonry in this portion of the wall is be 8 feet thick

Coping. The walls of the lower story are to be surmounted by a coping of Quincey granite of the pink variety. It is to be moulded on the outer face. The top of the coping is to be 23 feet 6 inches above the foundation.

Shaft. This is to be octagonal in plan and 26 feet in plan from outside to outside

Stone portion of the walls 3 feet in thickness and of granite with good quarry faces, joints cut to lay ½ of an inch and rise of the stone to be 16½ inches

The height of the shaft up to the belt course under the tank room is to be 103 feet above foundation. From the bottom of the belt course to the top of the coping on which rest the tank and the walls of the tank room is to be 8 feet.

Tank Room. This is to be octagonal in plan and 28 feet 4 inches from out to out of parallel walls. Walls 15" thick and of granite Whole height of room 29 feet There are to be 16 windows in the tankroom.

Roof The roof is to be 48 feet high and of form shown in plan, to have a zinc cornice around the first and second sections and on top, to have the angles covered with copper. It is to be slated, the slates passing under the copper at the angles. The roof is to be tied to the tower by 8 wrought iron ties 2"x1½" and turned up 12 inches under the bottom of the tankroom walls. The frame work is to be of the best white pine.

Lookout Room. ~~Between~~ the sections of the roof is to be the lookout room with its floor 158 feet 8 inches above the foundation

Brick Lining From the foundation to the coping under the tankroom will be a brick lining 8 inches thick, and with an air space, between it and the stones of the walls, of 4 inches.

Total height of the tower above foundation 18? feet 6 inches.

Stories The interior of the tower below the tankroom will be divided into 6 stories 18 feet and 1 inch between joints. The floors are to rest on wrought iron I shaped beams which pass through the brick lining 3 inches. Each story 18 feet 1 inch between joints

Stairs. These are to be of iron, cast treads and wrought frame work and in each story to wind from one side around to the opposite side, or occupying 5 sides, the landing on each floor to be vertically over that of the preceding.

Tank. The tank is to 21 feet 6 inches diameter, 22 feet height and of cylindrical form.

It is to be made of best wrought iron plates and welts each 3/8 of inch thick, the welts 9 inches wide

The edges are to be planed so as to form a close butting joint, and the joints to be double riveted with rivets 3/4 inch in diameter and to be so placed that any three adjacent rivets of the two rows shall be at a distance apart of 2 ?? inches from center to center. The tank is to rest on 5 wrought iron I shaped beams.

All pipes are fastened to the walls of the tower by iron clamps secured by bolts which are anchored to the walls

Engine House

Foundation. Prepared by leveling off the rock.

Substructure. The north end wall is to be 6 feet 6 inches thick at its base and stepped to 45" thick at top. South end wall is to be 5 feet 1 inch thick at the bottom, of the sides and 4 feet 6 inches above boiler house roof. In the middle these walls are to 9 feet 9 inches thick from bottom to top. The rear wall is to be 4 feet 5 inches thick throughout and the front wall 4 feet 1 inch at top, 6 feet at bottom.

These walls are of gneis.

The copings at the top are to be of granite.

The foundations for the pumps are to be of hammer dressed granite.

There are to be two brick walls to each engine extending from the bottom to the girders supporting the steam cylinders of the engines. They are to be, in the middle 4 feet thick from the bottom to the top and at the bottom of the sides 4 feet thick, stepped to 2 feet thick at top

The bottom of the basement is to be covered with gravel concrete 1 foot thick.

Suprstructure. The outside dimensions of the walls are to 58 feet 4 inches by 34 feet 4 inches and the top of the coping on which they rest to have the same elevation as the engine room floor, viz: 155 feet 10 inches above low tide. The walls are to built of granite laid in regular courses. They are to have a brick lining 8 inches thick with an air space of 2 inches between it and the stone.

Roof. It is to be a hip roof, the frame of chestnut, to be boarded with clear white pine and covered with slate laid 9 inches to the weather. The hips and ridges to be covered with 14 oz. copper plate.

The whole is to be finished in the best manner.

Pumping Engines

Steam Cylinder. The steam cylinder, of the engine to be erected first is to be of cast iron It is to be double shell. The lower head to be cast in and to have the stuffing box bolted to it with wrought iron bolts passing through flanges. There is to be a valve seat at each end having an exhaust and induction port cast in. The exhaust ports open into the anular space between the inner and outer shells of the cylinder. The upper head is to be secured by bolted flanges.

Valves and Valve Chests There will be two valve chests, one at each end of the cylinder secured to it by bolts. They will be cast in one piece together with a steam passage way connecting the two, and also to the lower will be cast the valve-stem-stuffing boxes. There will be a cover bolted onto each valve chest. The cover to be finished on the outside.

There will be a valve in each chest of the kind usually denominated "D" valve. They will be connected by two rods of wrought iron passing through the steam channel way and secured to the valves by nuts. They will be operated by two valve stems secured to the lower valve and passing down through the stuffing boxes, to the valve lever.

Steam Piston. The steam piston is to be cast double shell and strongly ribbed. It is to be packed with rings kept snug by steel springs and held in place by a cast iron follower plate secured by screw bolts. The hub bored to receive the end of the piston rod.

Condenser. Underneath the steam cylinder and at side opposite the valve chest is the condenser, a closed cast iron vessel with a hemispherical top and communicating with the annular space in the steam cylinder by a cast iron pipe. At the bottom, the condenser is bolted to its valve chamber, a horizontal cast iron pipe, having a rectangular cross section and resting on two wrought iron "I" shaped beams which support the whole and are themselves supported by the brick walls mentioned in the description of the engine house. The lower chamber has a rubber valve closing against a grillage

Steam Piston Rod. The steam piston rod is of best wrought iron, its upper end turned to fit the hub of the piston. It is coated, as far as it enters the small pump, with composition. Its lower end secured to the small pump piston as will be described presently.

Small Pump Cylinder. This is to be of cast iron, lined with composition. Its upper chamber is cast on and is merely an enlargement of itself, fitted with a flange to which is secured the head of cast iron. The head is fitted with a stuffing box having composition gland through which the steam piston rod passes. At the side of the chamber, is cast a nozzle fitted with a flange to which is secured the end of the chamber of the condenser.

The lower end of the cylinder has a water chamber cast on to it. At each end of the water chamber is an opening fitted with a flange. To one of the flanges is bolted the foot valve chamber and to the other the check valve chamber.

The water chamber has in its bottom a stuffing box of cast iron through which a hollow cast iron piston rod. The upper end of this rod is bored to fit the lower end of the steam piston rod. and it is also turned on the outside to fit the small pump piston

Piston. The small pump piston is cast in two parts, each part consists of a hub and flange, the hubs bored to fit the end of the hollow piston. The lower one is put on first resting against a shoulder on the hollow piston. It has the end with the flange on it, down. The other is then put on with the flange end down, thus leaving a space for the piston packing. The ends of the two piston rods are kept together by a strong steel key having a rectangular cross section

Chek valve. The check valve for the small pump is what is called the "double beat" valve. It closes upon two circular "end wood seats". The upper end of its chamber has a flange with a horizontal face. The valve opens upward.

Air Chamber. This is a cylindrical pipe having upper end hemispherical. Its lower end is flanged and bolted to the flange of the chek valve chamber. On one side of the air chamber is cast a flanged nozzle, to which is bolted the pipe leading to the tower tank. The air chamber rests upon the the valve chamber, which is supported by an "I" shaped beam. This is in turn supported by the above mentioned brick walls.

Foot Valve and Chamber. The foot valve is precisely like the check valve. The valve chamber rests upon an iron beam supported like the others. The lower end of the chamber has a cast iron flange with the plane of its face vertical.

Conical Valve Chamber. This is bolted to the foot valve chamber, at its upper end is cast to a pipe coming from the upper chamber of the main pump. At its top is a head bolted to flange on the chamber. The head is provided with a stuffing box throug which passes the conical valve rod. The head supports a cast iron arch piece having in its crown a nut and the valve rod with a screw cut on it passes throug^h the nut. On top of the valve rod is a hand wheel for working the valve. The valve is conical and its object is to shut off the water from the small pump when necessary.

Main Pump Cylinder. The main pump cylinder is of cast iron. To its upper chamber is secured the head. The head is provided with a plunger stuffing box. On opposite sides of the upper chamber is cast a flanged nozzle.

Air Chamber, This a cylindrical vessel with a hemispherical head. and having its lower end bolted to a strong section of horizontal pipe. This is all supported by two strong beams resting upon the brick walls. One end of the horizontal pipe is bolted to one of the flanges of Pump chamber. The other end is bolted to the pipe leading to the reservoir.

Check Valve and Chamber. The check valve is a rubber valve and closes against a cast iron grillage seat. The chamber is of cast iron, rectangular in section. To its upper end is bolted the pipe leading to the small pump. It is itself bolted to that other flange of the upper chamber of the pump. It also has cast to it a pipe with a vertical axis. Both this pipe and the pump barrel are flanged at their lower ends, flanges having faces down and to these is bolted the lower chamber of the pump. This lower chamber is rectangular in cross section. Its position is horizontal, with one end resting upon a raised bed piece which stands upon the granite foundation. The other end of this chamber is flanged, to it is bolted the foot valve chamber.

Foot Valve Chamber. The axis of this is an irregular, reversed curve having the foot valve seat in a horizontal position at the junction of the two curves. The chamber has cast two supporting pieces and rests upon the granite foundation. It thus serves as a support to end of the lower chamber of the pump, to which it is bolted. Between these supports it is fastened the pillow block bed plate which is bolted; both to the supports and to the granite foundation.

The foot valve chamber has, above the valve, a "manhole" through which to get at the valve when necessary.

Foot Valve. This consists of two circular iron plates, concentric with each other and stiffened by flanges, On the underside of the plates, sheets of rubber which set down to the seats and make a water tight joint and serve to deaden the blow when the valve comes down. The valve close over corresponding annular orifices in the valve seat. The edges of these orifices are rounded to facilitate the passage of water and to prevent cutting the rubber.

Main Pump Plunger. This is a hollow cylinder having its upper end bored to fit the lower end of the hollow piston mentioned before, The outside of the upper end is turned to received the crosshead hub. The whole is fastened together by a strong steel key with its section rectangular. The lower end going down into the pump cylinder is closed; its head having cast to it, within the cylinder and strongly ribbed, a hub which is bored to fit the bucket rod. The bucket rod is of wrought iron and fastened to the hub with a strong steel key. It is turned the whole length and has fitted to its lower end the bucket.

Bucket. This consists of a heavy cast iron ring and hub with thin wide arms all cast together. A follower is bolted to the under side to secure a lignumvitae packing. The edge of the ring and upper end of the hub are provided with groves in which are inserted endwood valve seats for a double beat valve. This works up and down, guided by the bucket rod. Bucket is secured by a nut underneath.

Cross Head. We have already described the hub. The arms extend in opposite direction and rectangular in cross section except at the ends which are cylindrical and fitted with bearings for the connecting rods.

Crank Shaft. The crank shaft is of wrought iron. It is situated under the pump and in the prolongation of its axis. I runs in two pillow blocks fastened to the foundation and bed plate already described, by means of strong anchor bolts. Each end projects out far enough to receives a flywheel.

Fly Wheels. There are two fly-wheels of equal sise and weight. The arms of one fly wheel are parallel to the corresponding arms of the other. In one of the arms of each wheel is fitted a crank pin, so that the wheels serve as two cranks with parallel arms and of equal length. The common axis of these pins is parallel with that of the cross head. They receive the lower ends of the connecting rods.

Connecting Rods.

Valve Gear. In one end of the crosshead is a steel pin which slides up and down in a grove in a vertical shaft. The shaft turns in standards bolted to the brick walls On its upper end is a bevel pinion gearing into a bevel wheel three times its size fitting to a rock shaft. An arm running out from the rock shaft has in its end a pin which work in a slot in the end of the valve lever. The grove in the shaft is of such form as to give it a rotatory motion, by means of which motion is communicated to the valves.

For further particulars refer to the table of data and to drawings.

TABLE OF DATA

Reservoir

Length of one side at foot of interior slope	276 feet; inches.
Depth of water	16 "
Capacity	10.794.178 gallons
Section of Embankment.	
Interior slope 3 horizontal to 2 vertical.	3/2
Exterior "	7/4
width of top	11 feet
Dimensions of parapet walls	2 ft by 2 ft
Coping of parapet walls	1 foot by 3 feet
Elevation of top of puddle wall above low tide	221 feet
Greatest Depth of puddle	32 "
Thickness at top "	4 "
" " 16 feet from top	10 "
" " bottom	10 "

Composition of puddle	2 Clay 1 Earth

Gate Houses.

Dimensions of plan of influent gate house	27.5" x 27'
" " " " effluent " "	36' x 27'
Height of either	20 feet
Diameter of well	3 feet
" " each sewer	3 "
Diameter of each induction pipe	20 inches

Tower

Diameter at base, outside	29 feet
" " " inside	18 "
" of shaft "	18 "
" " " outside	26 "
Elevation of bottom of tank room above foundation	111 "
" " top of tower " "	188 " 6 inches

Tank.

Interior diameter	21 feet 6 inches

Depth of tank	22 feet
Thickness of plate and welt	3/8 inch
Diameter of rivets	3/4 "
Depth of water	20 feet
Capacity	49368 gallons
Total weight of tower and tank	7.268.783 lbs.

Pumping Engine.

Steam Cylinder.

Diameter	32 inches
Length of stroke	6 feet

Piston Rod

Diameter	5 inches
Length	13 feet 8 inches

Small Pump

Diameter of cylinder	14 inches
" " hollow piston rod	12 "
" " induction pipe	7 "

Diameter of eduction pipe	7 inches
Length of stroke	6 feet
Main Pump	
Diameter of cylinder	32 inches
Length of stroke	6 feet
Diameter of induction main	30 inches
" " eduction "	20 "
Crank Shaft	
Diameter of Shaft	9 inches
Length	5 feet 6 inches
Weight of fly wheels and crank shaft	29029 lbs.
Weight of reciprocating parts	8000 "

COMPUTATIONS

Reservoir.

Embankment. In computing the strength of the embankment we will first consider the puddle and then the embankment of earth, using the following data.

Composition of puddle 2 of clay and 1 of earth

Weight per cubic foot of clay (Moseley)	120 lbs.
" " " " " compact earth	99 "
Breadth of base of puddle	10 feet = b
Volume " " taking portion 1 foot in length	274 cubic feet
Weight " " " " " "	30951 lbs = W
Depth at highest point	32 feet = h
Elevation of top of puddle above low tide	221 "
" " free surface of water " " "	221 "
Depth of water	16 " = x
Weight of water per cubic foot	62.4 = w

Then we have for the moments.

$\frac{1}{2}\mu x^2(h-\frac{2}{3}x)$ = Moment of pressure = $8 \times 62.4 \times (32 - \frac{2 \times 16}{3})$ = 10679

$\frac{Wb}{2}$ = " " Weight = $30951 \times \frac{10}{2}$ = 154755

Modulus of safety for overturning = $\frac{154755}{10679}$ = 14.5

For slipping we must take the pressure of the water at the bottom of the reservoir. This is resisted by all the friction produced by that portion of the puddle lying above the bottom of the water.

Then we have coefficient of friction for clay (Rankine) 1

" " " " earth 1.19

Taking mean coefficient we have 1.1

Weight of 16 ft depth of puddle from downward 13429 lbs.

Friction produced = 13429×1.1 = 14772 lbs.

Pressure of water = μx = 16×62.4 lbs = 998 lbs.

Modulus of safety = $\frac{14772}{998}$ = 14.8

Next take the portion of compact earth outside of the puddle and find its modulus for slipping.

Weight producing friction 26136 lbs

Coefficient of friction for earth (Rankine) 1.19

Then friction produced = 31101

Pressure of water same as before = 998

Modulus of safety = $\frac{31101}{998}$ = 31

Total resistance to slipping = 45871 lbs

Modulus of safety 45 "

It is unnecessary to calculate the modulus of safety for the outside earth against overturning, as it will slide before turning.

The earth within the embankment need not be considered as it is supposed to become saturated with water and its office is to protect the puddle from wash. It is itself protected by the slope wall, both from wash and from sliding inward when the water is drawn out from the reservoir.

Gate Houses. The only portions of these which have strains which are not counteracted by the water itself, are the pipes and and the partitions of the water and gate chambers. The pipes having been subjected to a test of 300 lbs bursting pressure, per square inch, as they sustain nothing near that amount of actual pressure are perfectly safe.

For the partition walls we will take the most unfavorable one which is that in the influent gate house. We will take a slice of one foot of its length for our computations. Then we have the following data:

Height of wall = h =		20 feet
Thickness " " = b =		5 "
" " brick facings		2 "
" " concrete filling		3 "
Depth of water = c =		16 "
Weight of brick in slice considered =	20×2×112 lbs =	4480 lbs. (Mosely)
" " concrete " " " =	20×3×133 " =	7780 " "
Total weight of slice " =		12260 " = W

Then for moments we have Moment of resistance = $\frac{Wb}{2} = \frac{12260}{2} \times 5 = 30650$

" " " " " " " pressure = $\frac{wc}{2} \times (h - \frac{2c}{3}) = \frac{62.4 \text{ lbs} \times 16}{2} \times (16 - \frac{32}{3}) = 2645$

Modulus of safety against overturning = $\frac{30650}{2645} = 11.5$

As the wall is short and firmly supported at the ends it acts as a plate band and therefore is perfectly safe.

It is unnecessary to compute its modulus for sliding as the concrete has no joints

Tower

All that will be considered in regard to the strength of the tower itself is its liability of turning over on one edge of its base, by the action of the wind, of turning over on the edge of the base of the tank room by the same agency and the probability of the coping being turned by the weight above it.

Turning of whole Tower. The surface upon which the wind acts is equal to the vertical projection of the tower and roof. Its point of application may be taken at the center of gravity of the surface. Then by reference to the drawings we have the following data:

Height of body of tower and tank room	140 feet
Average diameter " " " "	29 "
Height of roof above its base	48.5 "
Area of vertical projection of tower	4060 square feet
" " " " " roof	703 " " = A'
Total area	4763 " " = A
Width of base of tower	29 feet = b

Height of center of gravity of roof above its base = $\frac{48.5}{3}$ = 16.17 feet

" " " " " " body of tower " " " " = $\frac{140}{2}$ ft = 70 "

Then distance from center of gravity of body of tower to common center of gravity : whole distance between center gravities of parts as the areas of the projection of roof is to whole area. Hence we have distance = $\frac{86.17 \times 703}{4763}$ = 12.7 ft

Height of center gravity of whole projection above base of tower = 70+12.7 = 82.7 feet = l

Total weight of tower and roof exclusive of tank	7233723 lbs. = W
" " tank room walls	663740 " = W'
" " roof	102.558 " = W''.
Area of vertical projection of tank room	841 sq feet = A'
Width of base of tank room	29 feet = b.

Then for moments we have moment of weight = $W\frac{b}{2}$ = 7233723 × $\frac{29}{2}$ = 104888983

At 50 lbs per square foot pressure " " pressure = 50 lbs × A × l = 50 × 4763 × 82.7 = 19766450

Modulus of safety = $\frac{104888983}{19766450}$ = 5.4

As 50 lbs per square foot is a greater pressure than any wind which we have, exerts, there is no danger of the tower being blown over. Furthermore the weight of the tank full of water will tend to increase the stability

Turning over of the roof and tank room.

Height of center gravity of tank room above base of walls = 14.5 feet

Then for height of center gravity of whole above base we have $\frac{30.67 \times A''}{A} = \frac{30.67 \times 7.03}{15.44} + 14.5 = 14 + 14.5 = 28.5 = l$

Moment of weight $= \frac{W + W''}{2} b = \frac{669740 + 102558}{2} 29. = 11154821$

" " pressure $= (A' + A'') 50 \times 28.5 = 15.44 \times 50 \times 28.5 = 440040$

Modulus of safety $= \frac{11.154.821}{2200200} = 5$

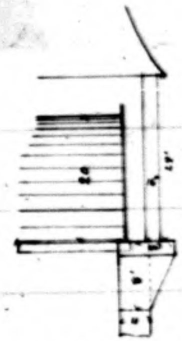
The roof cannot blow off as it is tied to the wall of the tank room with 8 strong wrought iron ties

Stability of the coping. Take that portion of wall and roof resting on 1 foot in length of coping. By looking at the drawing of the tower it will be seen that the coping, on which stands the tank room, projects beyond the walls of the tower and is supported by brackets reaching down 8 feet below the top of the coping. Also that a vertical line through the cross section of tank room wall, at its center gravity overhangs the face of the wall 6" inches. Then taking 1 foot of length of coping and of wall down to the foot of the bracket we have for that portion of the weight which lies within the face of the wall 5248 lbs = W

Thickness of wall at bottom of brackets — 4 feet = b

Weight of slice of wall of tank room = W = $\frac{663740}{88}$ = 7542 lbs. Lever arm = 6 inches = ½

" " corresponding portion of roof = $\frac{102558}{88}$ = 1165 lbs. " "



Then moment of W = 5248 × ½ = 5248 × 24 = 125952

" " " W' = 7542 × ½ = 7542 × 6 = 45252

Modulus = $\frac{125952}{45252}$ = 2.8

This is on the supposition that the wall is left free to turn over about the joint at the foot of the brackets. and that the joints are all perfect. The roof however acts as a tie beam to keep the top of the wall from moving outward making, necessarily, three joints of rupture instead of one. The weight of the roof also tends to prevent such opening of joints. Beside the weight of the tank full of water. has not been considered. which will also when added to the weight of the coping increase the stability. But it is not safe to depend upon that. Beside the deterioration of the mortar in the joints makes it necessary that something should be done to further secure the coping. This might be accomplished by ties reaching from the inner edge of the coping to some of the floor beams below.

Beams supporting tank. There are five wrought iron "I" shaped beams supporting the tank. As the middle one is as long as any we will consider that

The distance from center to center of the beams is 2.66 feet

Weight resting upon the span, is a load uniformly distributed of a volume of water, = 20 feet × 2.66 × 16 × 62.4 = 53115 lbs. = W Span = 16 feet

Let b_1, d_1 = breadth and depth of upper flange = 8" × 1.5". A' = Area = 10 sq. inches

" b_2, d_2 = " " " " lower " = 6" × 1". A" = " = 6 " "

" b_3, d_3 = " " " " Web = 13.75 × 1" A_3 = " = 13.75 " "

" A = area of whole section = 29.75 " "

Then from (Moseley's mech's) Art. 408 $S = \frac{W x c_1}{2I}$. In which S = strain at distance from the neutral line, = c_1; x = distance from center of gravity of half of beam to the abutment or wall; I = moment of inertia of the section about its center of gravity

Then (Moseley's Mech's Art. 365) $I = \frac{1}{12}(A_1 d_1^2 + A_2 d_2^2 + A_3 d_3^2) + \frac{1}{4}\left(\frac{4A_1A_2 + A_1A_3 + A_2A_3}{A}\right)d_3^2 = 942.88$

Also from same Article $hA = \frac{1}{2}(d_1 + d_3)A_1 - \frac{1}{2}(d_2 + d_3)A_2 = 1.038$ = distance between center of gravity and the center of the web.

Then distance from neutral axis to center of $A_1 = \frac{1}{2}(d_1 + d_3) - h = 6.467$

" " " " " " " " $A_2 = \frac{1}{2}(d_2 + d_3) + h = 8.408$

Substituting in the value for S for upper flange $S_1 = \frac{53115 \times 48 \times 6.467}{2 \times 942.88} = 8788$ lbs.

$S_2 = \frac{53115 \times 48 \times 8.408}{2 \times 942.88} = 11357$ "

Rankine gives for wrought iron: tensive strength 60000 to 70000. crushing 36000 to 40000

Taking a mean for each and, Modulus for upper flange $= \frac{38000}{8788} = 4.3$

" " lower " $= \frac{65000}{11357} = 5.7$

The upper is a little too small. But as part of the load is taken off by the other beams and as the beam projects over at the ends 20" and bears a proportionat load which relives the strain in the middle in a measure, it is strong enough.

Tank. Take one of the riveted joints at the bottom of the side for computing the strength. The following are the data required in calculation

D = diameter of tank = 21.6 feet H = depth of water = 20 feet

t = thickness of plate = 3/8 inch d = diameter of rivet = 3/4 inch

c = distance between from center to center of rivets = 2 5/8 inches.

Formula (123) (Lectures) $(c-d)t = \frac{\pi d^2}{2}$ $(2\frac{5}{8} - \frac{3}{4})\frac{3}{8} = .70$ inches $\frac{\pi \frac{9}{16}}{2} = .88$ inches

Then sections of plates and welts are to sections of rivets as .70 to .88

When sections are equal the strength of double riveted single welt joint = .65

that of plate. By substituting all values in the formula except c and solving for c we have c = 3" Then we have the space between the rivets = $1\frac{8}{8}$ But it is actually but $1\frac{5}{8}$ ∴ 18 : 15 = .65 : x = .54 that of the plate.

<u>Strength of 1 inch in length of the plate</u> = $\frac{3 \times 36000}{8}$ = 13500 lbs

Actual strength per inch in length of riveted joint 13500 lbs x .54 = 7290 lbs.

This is subjected to an actual pressure of a 21 foot column of water with a base of 1 sq inch multiplied by $\frac{21}{2}$ 12 + 3. In the column are 240 cubic inches weighing 8.68 lbs ∴ ($\frac{21}{2}$ 12 + 3) 8.68 = 1020 lbs. This is sustained by 1 inch in length of plate. ∴ Modulus = $\frac{7290}{1020}$ = 7.1

This is a safe modulus and if as some contend American boiler plate is superior to that of other countries the modulus will be still greater

Flow of Water.

Aqueduct to Pump Cylinder. The following are the data for calculating the losses from the Aqueduct to the middle of the pump cylinder.

Quantity of water to pass through this portion in 10 hours 2100000 gallons

As the pump draws water from the aqueduct but half the time, the number of cubic feet per second is 15.60 cubic feet

This is during the up stroke of the bucket.

The formulae are obtained from the 1st volume of Weisbach's Mechanics. The number of the article alone will accompany the formulae.

For entrance into 30" pipe (Art. 325) $\zeta_1 = \zeta + .303 \sin \delta + .226 \sin^2 \delta$. $\zeta_1 = .505 + .303 \sin 8^\circ + .226 \sin^2 8^\circ$

$\zeta_1 = .6516$ $h_1 = .6516 \frac{v^2}{2g} = .6516 \frac{(3.175)^2}{64.4} =$ $h_1 = .0371412$ feet

1st curve. (Art. 334) $h = \zeta \frac{\beta^\circ}{180^\circ} \frac{v^2}{2g}$ and $\zeta = .131 + 1.847 \left(\frac{r}{R}\right)^{\frac{7}{2}}$; $\frac{r}{R} < .1$ $\frac{\beta}{180} = \frac{63^\circ}{180^\circ} = .35$

$h_2 = .131 \times .35 \times \frac{v^2}{2g} = .131 \times .35 \times \frac{(3.175)^2}{64.4} = .007206$ feet

2nd curve. $\frac{r}{R} < .1$; $\zeta = .131$; $\frac{\beta^\circ}{180^\circ} = \frac{90^\circ}{180^\circ} = .5$ $h_3 = \zeta \frac{\beta^\circ}{180^\circ} \frac{v^2}{2g} = .131 \times .5 \frac{(3.175)^2}{64.4} =$ .0102835 "

3d curve. $\zeta = .131 + 1.847 \times (.89)^{\frac{7}{2}} = .131 + 1.847 \times .45568 = .9726$ ∴ $h_4 = .9726 \frac{125^\circ}{180^\circ} \frac{(2.37)^2}{64.4} = .056869$ "

4th curve. $\left(\frac{r}{R}\right)^{\frac{7}{2}} = .3322$ $h_5 = \left[(.131 + 1.847 \times .3322) \frac{90^\circ}{180^\circ}\right] \frac{(2.1)^2}{64.4}$. $h_5 =$ .0506328 "

Foot Valve (Art. 342) $\zeta = \left(1.645 \frac{F}{F_1} - 1\right)^2 = \left(\frac{1.645}{.434} - 1\right)^2 = 7.84$ $h_6 = 7.84 \frac{(1.7)^2}{64.4} =$ .32736 "

5th curve. From lower chamber into pump barrel. $\left(\frac{r}{R}\right)^{\frac{7}{2}} = .46$ $\zeta = .981$; $\frac{\beta^\circ}{180^\circ} = .5$;

$h_7 = .981 \times .5 \frac{(2.8)^2}{64.4} = =$ .05984 "

Friction (Art. 330) $h_8 = \left(.01439 + \frac{.017963}{\sqrt{v}}\right) \frac{l}{d} \frac{v^2}{2g} = \left(.01439 + \frac{.017963}{\sqrt{3.175}}\right) \frac{140}{2.5} \frac{(3.175)^2}{64.4} = .21509$ "

$h = h_1 + h_2 + h_3 + h_4 + h_5 + h_6 + h_7 + h_8 = .6644$ feet = loss of head

From middle of pump to reservoir.

Quantity raised by Bucket	202.509	cubic feet	per minute		
" " " Plunger	241.693	"	"	"	"
" " " Small pump	23.712	"	"	"	"

In upward stroke the first resistance is for half the water passing around the plunger considered as throttle valve at angle of 40° with the axis of rectangular tube.

Amount of water per second $= \frac{6.750}{2} = 3.375$ $v_1 = \frac{3.375}{4.66} = .724$ (Table V page 447) $\zeta = 9.27$

$$h_1 = 9.27\frac{(.724)^2}{64.4} = .07546 \text{ feet}$$

In passing from the cylinder through upper chamber we take it as an elbow of 90° for the whole volume. (Art 333). $\zeta = .9457 \sin^2\delta + 2.047 \sin^4\delta$

$\therefore \zeta = .9457 \sin^2 45° + 2.047 \sin^4 45° = .984$ mean velocity $= v = 2.84$ $\therefore h_2 = .984\frac{(2.84)^2}{64.4} = .113$ feet

In passing from chamber into 20" pipe case of abrupt contraction.

(Art. 326) $\mu_n = \mu_0(1+.102n+.067n^2+.046n^3)$; $\frac{F}{S} = n = \frac{2.18}{4.66} = .47$

$\therefore \mu_{.47} = .815(1+.04794+.0148+.004775) = .87$ $\therefore \zeta = \left(\frac{1}{.87}\right)^2 - 1 = .318$

$v =$ velocity in 20" pipe $= \frac{6.75}{2.18} = 3.1$ $h_3 = .318\frac{(3.1)^2}{64.4} = .0474$ feet

Resistances for 20" pipe There is but one curve in which $\frac{r}{R}$ is not less than .1

Hence Art. 334 we have formulae $h = \zeta\frac{\beta°}{180°}\frac{v^2}{2g} = .131\frac{\beta°}{180°}\frac{v^2}{2g}$. For this case $v = 3.1$

1st Curve. $\beta = 65°$ $\frac{\beta°}{180°} = .361$ $h_4 = .361 \times .131 \frac{(3.09)^2}{64.4}$ = $.047291 \times \frac{(3.09)}{64.4}$ feet

2nd " " $= 52°$ " $= .29$ $h_5 = .131 \cdot .29$ " = $.03799 \times$ " "

3rd " " $= 34°$ " $= .19$ $h_6 = .131 \cdot .19$ " = $.02489 \times$ " "

4th " " $= 49°45'$ " $= .276$ $h_7 = .131 \cdot .276$ " = $.0362 \times$ " "

5th " " $= 17°$ " $= .094$ $h_8 = .131 \cdot .094$ " = $.012314 \times$ " "

6th " " $= 8°30'$ " $= .0047$ $h_9 = .131 \cdot .0047$ " = $.00061557 \times$ " "

7th " " $= 52°$ " $= .29$ $h_{10} = .131 \cdot .29$ " = $.03799 \times$ " "

9th " " $= 25°30'$ " $= .142$ $h_{12} = .131 \cdot .142$ " = $.0187 \times$ " "

8th " " $= 90°$ " $= .5$; $\frac{r}{R} = \frac{10}{36}$; $\left(\frac{r}{R}\right)^{\frac{7}{2}} = .00862$

$\zeta = .131 + 1.847 \times .00862 = .1469$ $h_{11} = .1469 \cdot .5 \frac{(3.09)^2}{64.4}$ = $.07345 \times \frac{3.09}{64.4}$ feet

Tangent friction. $h = \left(.01439 + \frac{.017963}{\sqrt{v}}\right)\frac{l}{d}\frac{v^2}{2g}$ $\therefore h_{13} = \left(.01439 + \frac{.017963}{\sqrt{3.09}}\right) 191.4 \frac{3.09}{64.4} = 5.895 \times \frac{3.09}{64.4}$ feet

$\therefore h = h_1 + h_2 + h_3 + h_4 + h_5 + h_6 + h_7 + h_8 + h_9 + h_{10} + h_{11} + h_{12} + h_{13} = 6.1744 \frac{3.1}{64.4} = 1.1564$ feet = loss

Foot valve weighs 224 lbs. area of valve exposed to pressure 644.″ pressure per inch = head of .79 feet lost. This added to the above gives for total loss in upward stroke of bucket $h = 2.618$ feet

Downward stroke of plunger.

A part of the water passes through the bucket valve in to the upper chamber

The remainder passes through the lower chamber, thence through the pipe connecting the upper and lower chambers, through a check valve, thence each side of the plunger and out.

To get the losses for each we first suppose all of it to pass through the bucket and 2nd that it all passes through the connecting pipe.

1st Supposition.

Volume per second 8.056 cubic feet

Through bucket (Art 342). $\zeta = (1.645\frac{F}{F_1} - 1)^2$. $\frac{F_1}{F} = .546$ in this case $\therefore \zeta = (\frac{1.645}{.546} - 1)^2 =$ 4.048 $v = 1.44$ feet $h_1 = 4.048 \times \frac{(1.44)^2}{64.4} = .1303456$ feet

End of plunger, taken as case of abrupt contraction. F annular area. G = section of barrel $\frac{F}{G} = n = .5$. Art. 326 $\mu_n = \mu_0(1 + .102n + .067n^2 + .046n^3) = \mu_{.5} = .815(1 + .102 \times .5 + .067 \times (.5)^2 + .046(.5)^3)$ $= .875$. $\zeta = (\frac{1}{.875})^2 - 1 = .304$ $h_2 = .304\frac{(2.88)^2}{64.4} =$ .038608 feet

For entering the 20 inch pipe, same as in upward stroke except a different value of v. Quantity to pass around the plunger considered as a throttle closed 40°. we have for $v = .865$ $h_3 = 9.27\frac{(.865)^2}{64.4} = .017532$ feet

Again whole of the water passes around 90° elbow mean section 2.18 sq. feet. For the same place in upward stroke ζ equaled .984 $v = 3.7 \therefore h_4 = .984\frac{(3.7)^2}{64.4} = .209$ feet.

Entering 20" pipe same as in up stroke with different value of v $v = 3.7$. As before $\zeta = 313$

$$\therefore h_5 = .313 \frac{(3.7)^2}{64.4} = .067416 \text{ feet}$$

Valve weigh 194 lbs. pressure per inch to raise it .51 lbs per inch. This is equivalent to a head of $h_6 = 1.1$ feet

Total loss by this supposition $h = 1.563$ feet

2nd Supposition.

First around curve of 180° deflection. $\frac{r}{R} = \frac{14}{21}$ $\zeta = .131 + 1.847\left(\frac{14}{21}\right)^{7/2} = .567$ (Art. 334)

$$h_1 = .567 \frac{180°}{180°} \frac{v^2}{2g} = .567 \frac{(1.8)^2}{64.4} = .01984 \text{ feet}$$

Second. Elbow 90° (Table page 434) $\zeta = .984$ $v = 1.73$ $h_2 = .984 \frac{(1.73)^2}{64.4} = .040176$ feet

Third. Check valve. Taken as a diaphram. (page 444) $\zeta = \left(\frac{F}{aF_1} - 1\right)^2$. F_1 = section of valve opening = 2.67 sq. feet F = Area of pipe = 4.66 sq ft. a depend upon the value of $\frac{F_1}{F}$ $= \frac{2.67}{4.66} = .57$ corresponding value of a (table page 444) .696 $\zeta = \left(\frac{4.66}{2.67 \times .696} - 1\right)^2 = 1.56$; $v = 1.73$

$$h_3 = 1.56 \frac{(1.73)^2}{64.4} = .0724 \text{ feet}$$

Fourth. Passing around plunger Same as first supposition except different value of v $v = 1.73$ $\therefore h_4 = 9.27 \frac{(1.73)^2}{64.4} = .430128$ feet

Fifth. Resistance in entering 20" pipe from pump chamber. Same as in first supposition with different value of v $v = 3.7$ $h_5 = 318\frac{(3.7)^2}{64.4} = .067416$ feet

Total loss $h = .63$ feet

Then loss in second supposition: to loss in first supposition = quantity going through bucket is to quantity going through check valve. ratio of resistances = $\frac{.63}{1.56}$.

∴ Quantity going through the check valve = $\frac{8.056}{3.48}2.48 = 5.73$ cubic feet.

We now take the value of v obtained from $Q = 5.73$ and substitute in the values for h_1 h_2 &c in second supposition and get losses which must correspond with those by the first supposition. Then we have

$$h_1 = .567\frac{(1.33)^2}{64.4} = .0155358 \text{ feet}$$

$$h_2 = .984\frac{(1.22)^2}{64.4} = .0227304 \text{ "}$$

$$h_3 = 1.56\frac{(1.22)^2}{64.4} = .0360360 \text{ "}$$

$$h_4 = 9.27\frac{(1.22)^2}{64.4} = .2131370 \text{ "}$$

$$h_5 = 3.18\frac{(2.6)^2}{64.4} = 0333900 \text{ "}$$

Total loss in pump $h = .3208292$ "

For losses in the 20" pipe take the values of S from the same case for the upward stroke and use $v = 3.7$ $h = 6.1794\frac{(3.7)^2}{64.4} = 1.309$ feet

Add the losses in pump and pipe we have $h = 1.63$ feet

This is the total loss for the down stroke of the plunger

Flow from lower to upper pump The water is drawn into this pump in the upward stroke and forced out, and into the tower tank, in down war stroke.

Quantity of water raised per second is .7904 cubic feet

Loss in suction pipe. (Art. 330) $h_1 = (.01439 + \frac{.017963}{\sqrt{v}})\frac{l}{d}\frac{v^2}{2g}$ $\frac{l}{d} = \frac{84}{7}$ $v = 3$ feet per second

$$h_1 = (.01439 + \frac{.017963}{\sqrt{3}})\frac{84}{7}\frac{3^2}{2g} = .004312 \text{ feet}$$

Aperture for stop valve. As the valve can be drawn up out of the way, we take the case as that of a diaphram. (Table page 444) $\zeta = (\frac{F}{aF_1} - 1)^2$

Area of pipe $= F = .267$ sq. ft. Area of orifice $= F_1 = .136$ sq. ft. $\frac{F_1}{F} = .5$, corresponds to value of $a = .681$

Then $\zeta = (\frac{.267}{.136 \times .681} - 1)^2 = 3.5$ $h_2 = 3.5\frac{3^2}{64.4} = 3.5 \times .14 = .49$ feet

Elbow 90° Deflection (Table page 434) $\zeta = .984$ $h_3 = .984\frac{v^2}{2g} = .984\frac{(1.95)}{64.4} = .05904$

Curve. (Art. 334) $h = \zeta\frac{\beta°}{180°}\frac{v^2}{2g}$ $\zeta = .131 + 1.847(\frac{r}{R})^{\frac{7}{2}}$ $v = 1.8$ $\beta° = 90°$ $\frac{r}{R} = \frac{4.5}{8} = .56$

$$h_4 = (.131 + 1.847(.56)^{\frac{7}{2}})\frac{90°}{180°}\frac{(1.8)^2}{64.4} = .011775 \text{ feet}$$

Foot valve. (Art. 342) $\zeta = (1.645\frac{F}{F_1} - 1)^2$. Area of pipe below valve = 95 sq inches. Area of aperture = 38.4846 sq inches. Area of valve ring 56.52 sq inches ratio of valve ring to pipe =

.595 ratio of orifice to pipe .405 $\frac{.405 + .595}{2} = .5 = \frac{F_1}{F}$ ∴ $\zeta = (\frac{1.645}{.5} - 1) = 5.29$ $v = 1.2$

$$h_5 = 5.29 \frac{(1.2)^2}{64.4} = .117967$$

Elbow. Deflection 90° as before $\zeta = .984$; $v = 1.34$ $h_6 = .984 \frac{(1.34)^2}{64.4} = .02755$ feet

For passing into the pump barrel we must consider half the water as flowing around the hollow piston acting as a throttle. Section of passage way 28 sq. inches. Section of valve = 84 sq inches. ratio = .333. Then by interpolation from the table (6) page 447. $\zeta = 11.47$ To get v take half the cross section of the chamber = .26 sq ft. and .3952 by it, we have $v = 1.52$ ft

$$h_7 = 11.47 \frac{(1.52)^2}{64.4} = .410626 \text{ feet}$$

The remaining portion may be considered as passing an elbow of 90° with mean sectional area of 207 sq. feet giving for $v = 1.9$ feet. Then as before $\zeta = .984$

$$h_8 = .984 \frac{(1.9)^2}{64.4} = .055104 \text{ feet}$$

Total loss = h = 1.176 feet

Downward stroke. In passing out of the pump barrel the resistances are the same as in the last two case Hence $h_1 =$ .055104 feet

$h_2 =$ .410626 "

For the curve under the check valve and for the check valve, the same as for the curve under the foot valve and for the foot valve $\therefore h_3 = .011775$ feet

$h_4 \; .117967$ "

Air chamber we may consider the water as first passing an elbow of 90° Then as before $\zeta = .984$ $v = 1$ foot $h_5 = .984 \frac{(1)^2}{64.4} = .01525$ feet

Entering a 7" pipe (Art. 326) $\mu_n = \mu_0(1 + .102n + .067n^2 + .046n^3)$ & $\zeta = \left(\frac{1}{\mu_n}\right)^2 - 1$ $\frac{r}{8} = \frac{226}{785} = n = .34$

$\mu_{.34} = .815(1 + .102 \times 34 + .067 \times (.34)^2 + .046(.84)^3) = .85$ $\zeta = \left(\frac{1}{.85}\right)^2 - 1 = .383$; $v = 3$ feet

$h_6 = .383 \frac{(3)}{64.4} = .383 \times .14 = .05362$

In flowing through the seven inch pipe the water is opposed by no curve in which $\frac{r}{R}$ is not less than one tenth. The velocity is 3 feet per second. (Art. 334) $\zeta = 1.31$

1st Curve. $\beta = 90°$ $R = 4$ feet; $\frac{\beta}{180°} = .5$ $h_7 = .131 \times .5 \times \frac{v^2}{2g} = .131 \frac{v^2}{2g} \times .5 = .131 \frac{3^2}{64.4} \times .5 = .01834 \times 5 = .00917$

2nd " " $= 65°12'$ " $= 10$ " " $= .36$ $h_8 = .01834 \times 36 = .0066024$ feet

3rd " " $= 52°$ " $= 12$ " " $= .29$ $h_9 = .01834 \times .29 = .0053186$ "

4th " " $= 34°$ " $= 20$ " " $= .19$ $h_{10} = .01834 \times .19 = .0034846$ "

5th " " $= 49°75'$ " $= 96$ " " $= .276$ $h_{11} = .01834 \times .276 = .00506189$ "

6th " " $= 83°$ " $= 13$ " " $= .46$ $h_{12} = .01834 \times .46 = .0084364$ "

7th " " $= 84°8'$ " $= 4$ " " $= .47$ $h_{13} = .01834 \times .47 = .0086258$ "

8th " Reverse curve. $\beta = 49° + 49° = 98°$; $R = 3$ feet $\frac{\beta}{180°} = .544$. $h_{14} = .01834 \times .544 = .00997696$ feet.

Tangent friction. (Art. 334). $h_1 = (.01439 + \frac{.017963}{\sqrt{v}})\frac{l}{d}\frac{v^2}{2g}$ $\frac{l}{d} = \frac{228' \times 12}{.7''} = 390.9$ $v = 3$

$$h_{15} = (.01439 + \frac{.017963}{\sqrt{3}})\, 390.9 \frac{(3)^2}{64.4} = 2.05 \text{ feet.}$$

$$h_1 + h_2 + \cdots\cdots + h_{15} = h = 2.77 \text{ feet}$$

Load on different parts

Elevation of surface of water in reservoir	221 feet
" " " " " " aqueduct	124 "
Difference	97 "
Hight due to loss in upward stroke of bucket	2.018 "
" producing pressure on bucket	99.018 "
Pressure per inch or bucket	43.06 lbs.
Area of bucket − area of rod = 804.25 − 9.62 sq. inches =	794.63 sq. inches
" " " − " " plunger = 804.25 − 415.48 " " =	388.77 " "
Strain on the rod = 794.63 × 43.06 lbs = =	34117 lbs
Water load on bucket 388.77 × 43.06 lbs. =	16740 "

Load on Plunger.

In the downward stroke the foot valve closes. Consequently the

the height through which the water is raised equals the difference in elevation between the free surface of water in reservoir and the middle of the pump cylinder.

Elevation of surface of water in reservoir =	221	feet
" " middle of pump barrel	109	"
Difference	112	"
Height due to resistence	1.63	"
" producing pressure on the plunger	113.07	"
Pressure per sq. inch	49.13	lbs.
Sectional area of plunger	415.48	sq. inches
Load on " 415.48 × 49.13 lbs =	20317	lbs.

Load on piston of small pump in upward stroke. In the upward stroke the piston only draws water from the upper chamber of the main pump, to the middle of the small pump cylinder

Difference in elevation of main pump chamber and middle of pump cyl.	13	feet
Height due to losses	1.18	"
" producing pressure on piston	14.18	"

Pressure per inch on piston		6.1 lbs
Effective area of piston		40.8 sq inches
Load on piston	40.8 x 6.1 lbs	= 248.9 lbs

Downward stroke of piston.

Elevation of free surface of water in tank		336 feet
" " middle of pump barrel		127.8 "
Difference		208.2 "
Height due to losses		2.05 "
" producing pressure		210.25 "
pressure per sq inch on piston		91. lbs.
Area of piston		40.8 sq inches
Load on "	40.8 x 91 lbs.	3713 lbs.

Load on air pump piston. Take it as only acting on the doward stroke, as the air pump is single acting and has but to throw the water out at its top in the upward stroke. Area of piston 134 sq inches

Assumed pressure per sq inch arising from Atmosphere 12 lbs.

Consequent increase of load in downward stroke 134×12 lbs = 1608 lbs.

Total Load

Upward stroke.

Water load	16989 lbs.
Weight of reciprocating parts + assumed weight of water in air pump.	8300 lbs
Total	25289 lbs.

Downward stroke

Water load	24030 lbs.
Air pump load	1608 "
Total	25638 "

Difference in favor of downward stroke 3.49 lbs.

Number of strokes per minute. 27.92 or double strokes 13.96

Fountain.

In computing the hight to which the fountain will throw water we have assumed the form of nozzle for which Weisbach made his formula It is slightly convergent (conically) and has its inner or entrance orifice rounded at the edges. we will suppose it to be 1 inch in diameter and length 20 times the diameter. (Art. 335). $h = [1 + \zeta_3 + (\zeta + \zeta_1 \frac{l}{d} + \zeta_2)\frac{d^4}{d_1^4}]\frac{v^2}{2g}$

Length of tangent in 6 inch pipe 336 feet.

First curve $\beta = 84°8'$ $R = 4$ feet

Second " $\beta = 97°3'$ $R = 13$ "

Third " $\beta = 17°$ $R = 13$ "

Fourth " $\beta = 90°$ $R = 4$ "

Difference in elevation between mouth of jet and surface of water in tank = 115 feet

(Art 334) $\zeta = .131 + 1.847(\frac{r}{R})^{\frac{7}{2}}$ $h = \zeta \frac{\beta°}{180°}\frac{v^2}{2g}$ $\frac{r}{R} < .10$ ∴ $\zeta = .131$ in all the curves

Assume 40 feet as the velocity at outlet. Then in 6 inch pipe $v = 1.111$ feet.

From Art. 330 $\zeta_1 = .01439 + \frac{.017963}{\sqrt{v}} = .01439 + \frac{.017963}{\sqrt{1.11}} = .03149$. $\frac{l}{d} = 751$ $\zeta_1 \frac{l}{d} = 23.649$

coefficient for short tube entering from tank .815. For first curve $\zeta \frac{\beta}{180} = .131 \frac{84.8}{180} = .0612$

Second $.131 \frac{97.3}{180} = .0693$ Third. $.131 \frac{17}{180} = .0125$ Fourth $.131 \frac{90}{180} = .0655$

∴ $115 = [1 + .32(.815 + 23.649 + .0612 + .0693 + .0125 + .0655)\frac{1}{1296}]\frac{v^2}{2g} = 1.339 \frac{v^2}{64.4}$ ∴ $v = 74.6$

Substitute this value in friction formula. $\zeta = .01439 + \frac{.017963}{\sqrt{\frac{74.6}{36}}} = .02686$ $\zeta \frac{l}{d} = 20.17186$

From which we have $v = 74.5$ feet $\frac{v^2}{2g} = 86.26$ feet $= s =$ height in vacuo

Height in air $= s_1 = s(1 - .00305 s)$ feet $= s(1 - .00305 \times 86.26)$ feet $= 63.57$ feet

Strength of Pipes.

The test for all the pipes was a pressure of 300 lbs per sq inch interior surface

30 inch Pipe.

Actual pressure due to column of water 24 feet in height 10.32

Strain upon 1 inch in length of one side = $\frac{D}{2} \times P' = \frac{30}{2} 10.32 = 154.80$ lbs

Thickness = $\frac{13}{16}$ inch Resistence to rupture per sq inch of metal = 15000 lbs.

Resistence to rupture of 1 inch in length of pipe = $\frac{13}{16} 15000 = 12187.5$ lbs.

Modulus $= \frac{12187.5}{154.8} =$ 72.9

" for the test. $\frac{12187.5}{4500} =$ 2.7

20 inch Pipe.

Thickness $\frac{3}{4}$ inch. Resistence to rupture of inch in length of side 11250 lbs

Strain from test $\frac{D}{2} \cdot P = \frac{20}{2} 300 = 3000$ lbs. Actual strain $\frac{20}{2} 49 = 490$

Modulus of test = 3.75 Modulus of actual strain 23

7 inch Pipe.

Thickness $\frac{9}{16}$ Resistence to rupture of 1 inch in length of side 8437.5 lbs.

Strain from test $\frac{D}{2} \cdot P = \frac{7}{2} 300 = 1050$ lbs. Actual strain $91 \times \frac{7}{2} = 318$.

Modulus of test 8 Modulus of actual strain = 26.5

SUMMARY

Reservoir

Embankment. In this computation the puddle was first taken and its moduli for slipping and for overturning found to be, respectively,

Moduli Slipping 14.8 Overturning 14.5

Then the earth embankment was considered with regard to sliding but not for overturning as it will slide first.

Modulus 31

Total against slipping 45.8.

Gate Houses. The only portion taken here was the partition wall between the water chamber and gate chamber of the effluent gate house. It consists of two parallel brick walls filled in with concrete, as the concrete has no joints it will not slip. Modulus for overturning, supposing it not to be supported at the ends, is 11.5

Tower.

The whole tower was considered with regard to being turned over about its base under the action of the wind taken at 50 lbs per square foot of vertical projection.

Modulus of safety 5.4

Roof and Tank Room Wall. Its resistence to turning over under the action of wind as in preceding case was taken and gave a modulus 5

Stability of Coping. The tank room wall has it center of gravity overhanging the face of the wall of shaft a horizontal distance of 6 inches. Its support is the weight of the coping and the roof acting as a tie to prevent its top from falling outward. But its modulus was calculated on the supposition that the roof was taken off.

Modulus 2.8

Beams suporting Tank. One of the middle beams having the longest span was taken and formulae Art. 408 Moseleys Mech's applied in the calculation. Modulus was found to be for the upper and lower flanges

Moduli: Upper flange 4.3 Lower flange 5.7

Tank The bottom of the riveted joint on one side was taken and formula 123 lectures the modulus of safety was found to be 7.1

Flow of Water

From Aqueduct to Pump The quantity to be raised by the pump in ten hours is assumed to be 210000 gallons and that is to be the actual requirement for the present.

Hight due to resistences .6644 feet

Upward stroke of Bucket

Quntity to be lifted per 10 hours.	908860 gallons
Height due to resistences in lifting	1,1464 feet
Loss from weight of foot valve	79 "
Adding height lost from Aqueduct to pump we have	2.618 "

Downward stroke of Plunger

Quantity to be forced up in 10 hours	1084778 gallons
Height due to resistences	1.63 feet

From lower to upper pump

Quantity per 10 hours	106419 gallons
Height due to resistences	1.176 feet

Downward stroke of small pump.

Quantity per 10 hours 106419 gallons

Height due to resistances 2.77 feet

Loads

Main Pump

For the bucket the load has to be raised through a height of 99 feet

Pressure produced per sq inch on bucket 43.06 lbs.

Load 16740 lbs.

Addional load of reciprocating parts 5300 "

Total for bucket 22289 "

For the plunger the load has to be forced to a height of 113 feet

Pressure per sq inch produced 49.13 lbs.

Load 20317 "

Small Pump

In upward stroke the load has to be raised to height of 14.8 feet

Pressure produced per sq inch of piston 6.1 lbs.

Load for upward stroke	248.9 lbs.
Load of water from condenser	300 "
Load for downward stroke is raised through a height of	210.25 feet
Pressure, per sq. inch, produced	91 lbs.
Water load	3713 "
Atmospheric load, from pump acting as air pump	1608 "

Total Load.

Upward Stroke	25289 lbs.
Downward "	25638 "
Difference	349 "

Number of double strokes 13.96

Fountain.

Height to which the water is thrown in air 63.57 feet.

Strength of Pipes.

Test. All the pipes subjected to bursting pressure per sq inch of 300 lbs.

30" Pipe.

Modulus for test	2.7
" " Service pressure	72.9

20" Pipe.

Modulus for test	3.75
" " service pressure	23

7" Pipe.

Modulus for test	8
" " service pressure	26.5

CONCLUSION

The object of this thesis has not been to exhaust the subject; but to take those parts for computation which appeared to be most important, or upon which depends the efficiency of the whole.

The order in which they are taken up is that in which the work progresses.

Consequently we have commenced with the reservoir.

In calculating the strength of the embankment it was deemed unnecessary to consider that portion of compact earth lying within the puddle as it is supposed to become saturated with water. Yet it serve as a protection to the puddle in protecting it from wash it is procted in turn, by the slope walls, both from wash and from sliding inward when the water is for any reason drawn from the reservoir. Without this portion of embankment the work is sufficiently strong as is shown in the summary.

In the gate houses all pressures from water have a counter pressure from the same, except the part considered which as is shown by the modulus (11.5) is safe and excepting the pipes which, as the pressure is very slight, were considered perfectly safe.

All connected with the tower as far, as considered, may be taken as perfectly safe, except the coping upon which rests the tank room walls and the roof. Although, this was taken in the most unfavorable condition, possible. Considered, as it would stand when completed and supposing, the joints all to be perfect, the mortar not to deteriorate in time, it would probably be safe. But as the latter conditions are not attainable, there should be some measures taken to increase its stability. This might be accomplished in various ways one of which would be to clamp the inner edge of the coping by ties reaching to the floor beams of some of the lower stories.

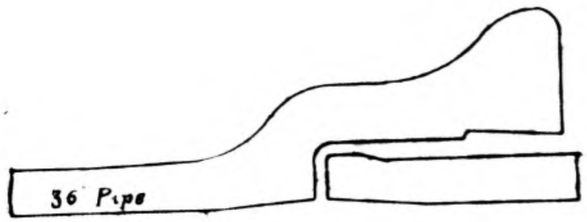
Upon the engine house no computations have been made. But as seen by the description of parts and a comparison of them with the like parts of other structures &c which have been calculated, they appear generally to be of sufficient strength.

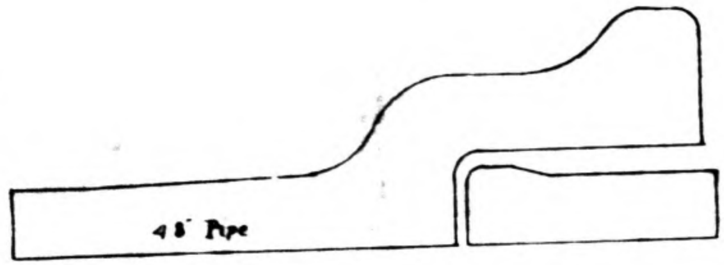
The computations upon the pumping engine have been only extended to the point of finding the load upon the parts and as shown by the calculations they are very nearly ballanced for the upward and downward strokes. The losses apear surprisingly small when a casual glance is taken, but when we consider the small velocity of the water it is not to be wondered at. It is possible that some losses may arise from the resistence of projecting points &c for the calculation of which no formulae are given. Yet, as there are not many such, it is reasonable to suppose such losses to be very small. We think from the general arrangement of the parts, that a calculation would, if, applied to all of them, prove the design of the engine to be very satisfactory and its capability of doing much more work than at present required of it, as unquestionable.

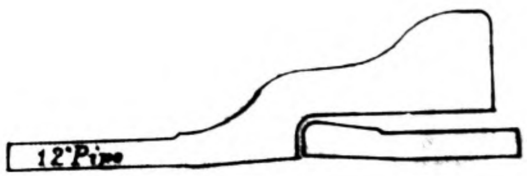
In calculating the strength of pipes it appeared desirable to first discover if possible whether the test of 300 lbs per sq inch would be liable to injure the pipe or over strain them. It is generally considered that, if the strain is not over one half the actual strength of the iron, it will not injure it and as shown by the calculations, the test applied left a margin of more than two and they can never be subjected to such a strain in service for which they are intended if properly laid and calked.

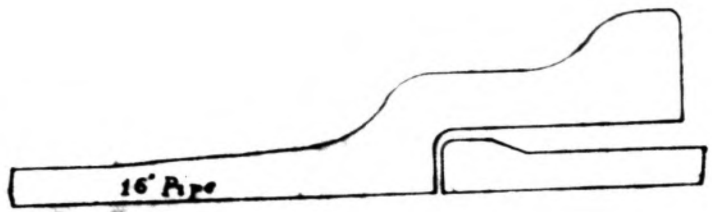
The computations upon the fountain were more a matter of curiosity than of utility. The 1 inch nozzle assumed is the most favorable form for throwing water. If a number of smaller ones should be used they would not be apt to throw water so high but by incling them slightly the jets would not meet quite as much resistence from the air.

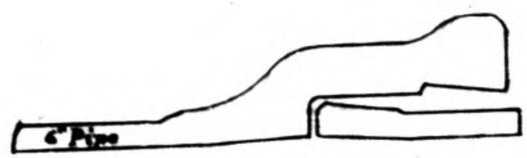
As none of the work considered has yet been subjected to that most sure, test of all (the test of actual service) we have not, at present, the satisfaction of knowing how nearly such test would confirm the above calculations. But if the execution of the work continues as well as it has begun and as well as it is designed it cannot fail to give satisfaction, and to be such a combination of utility and fine architectural effect as to make it one of the first attractions of the city which it waters











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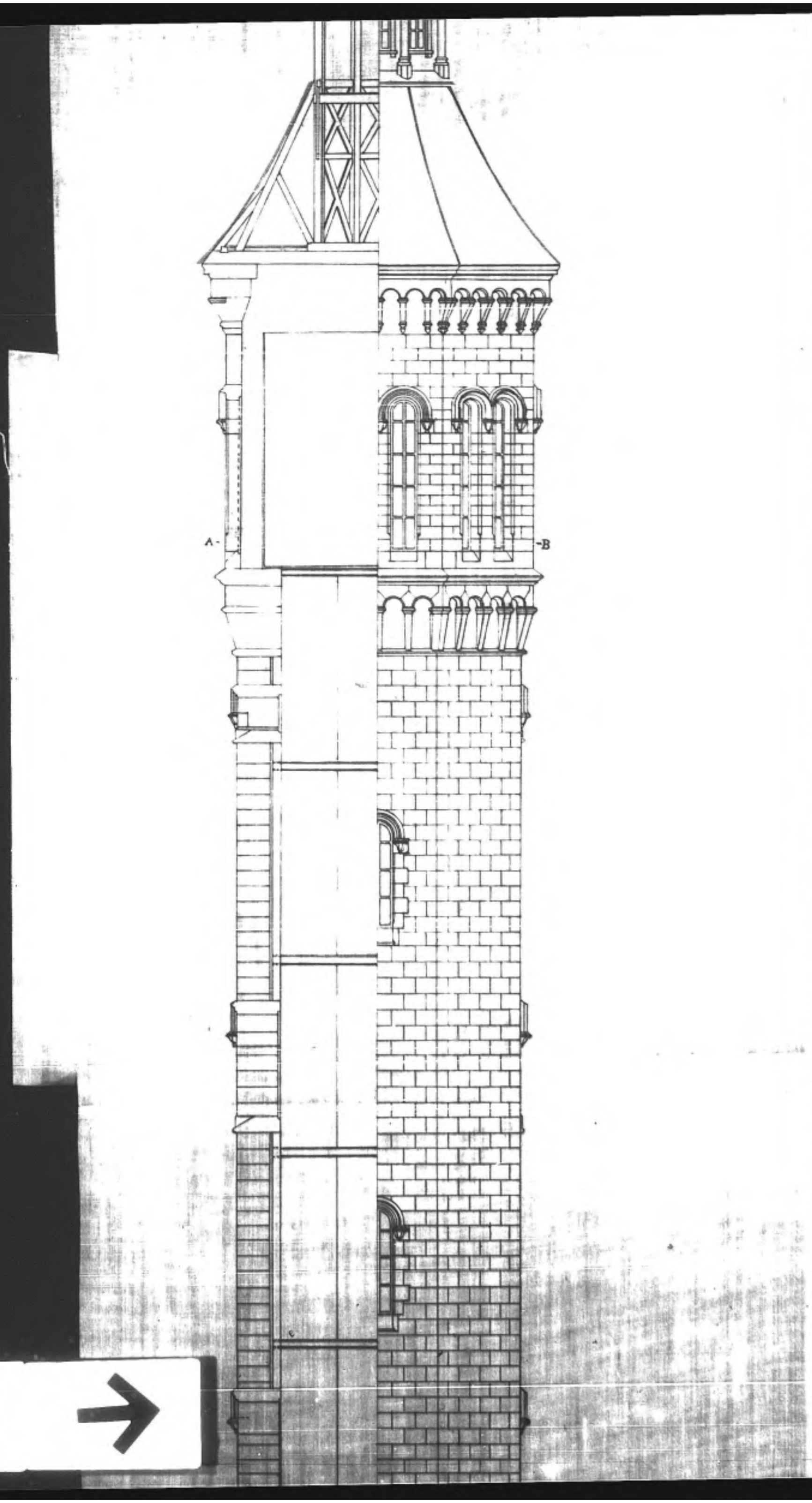

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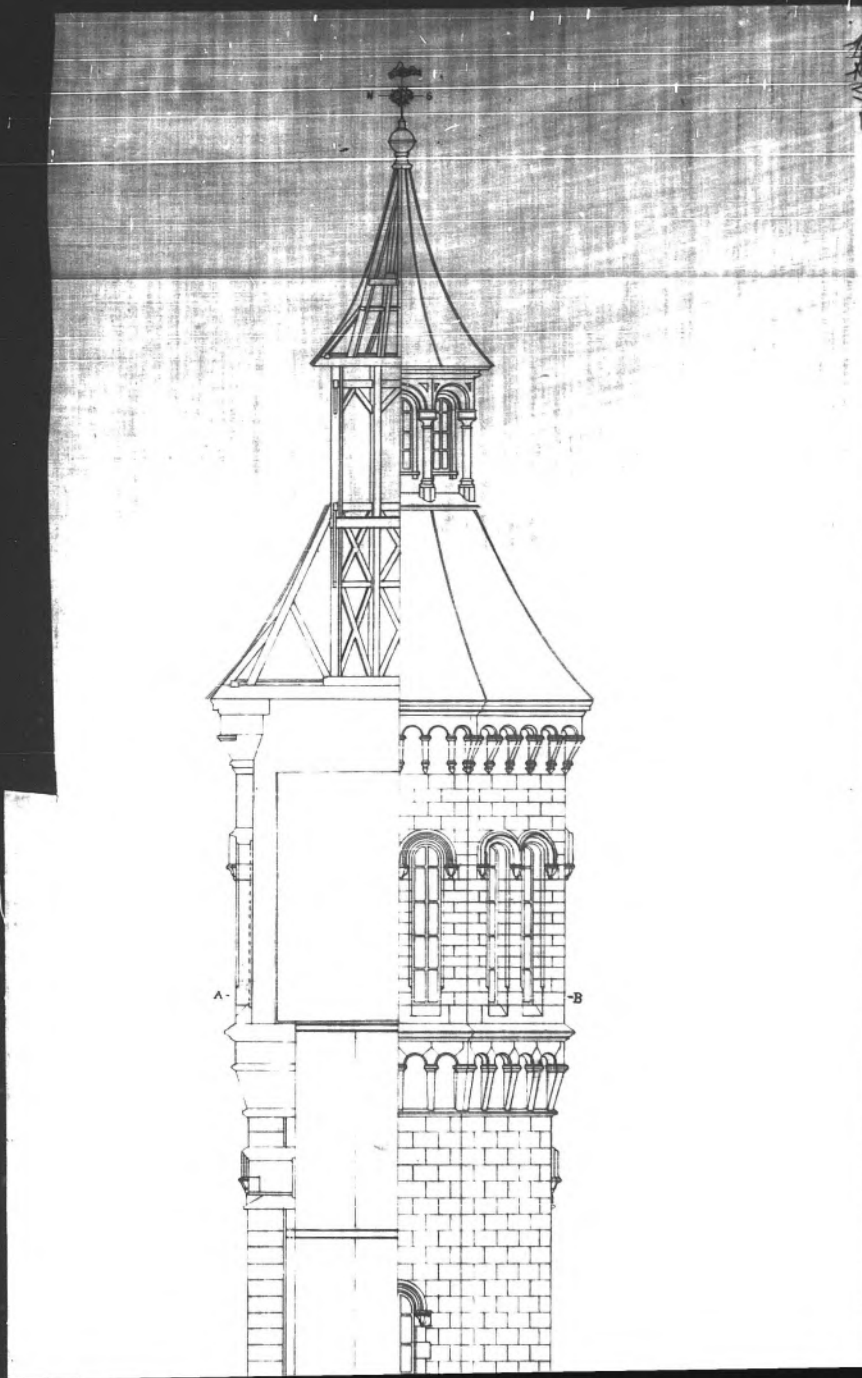

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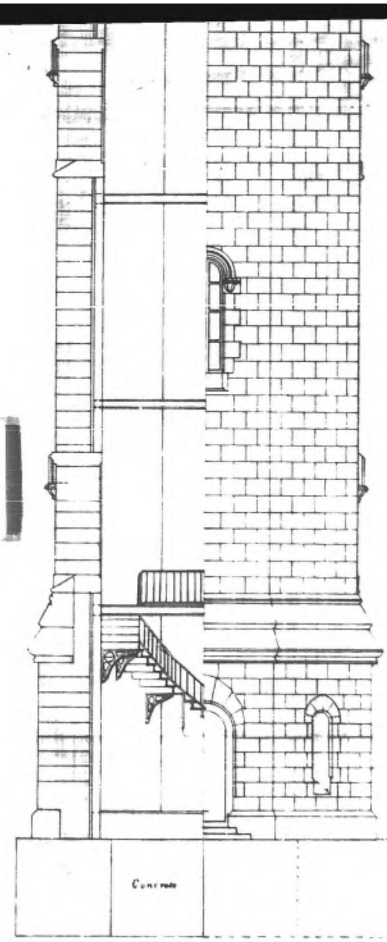
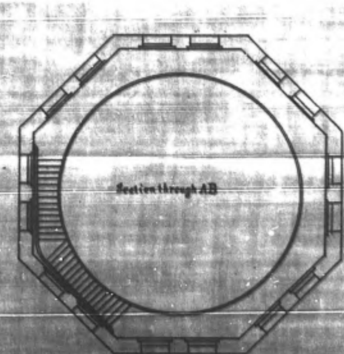
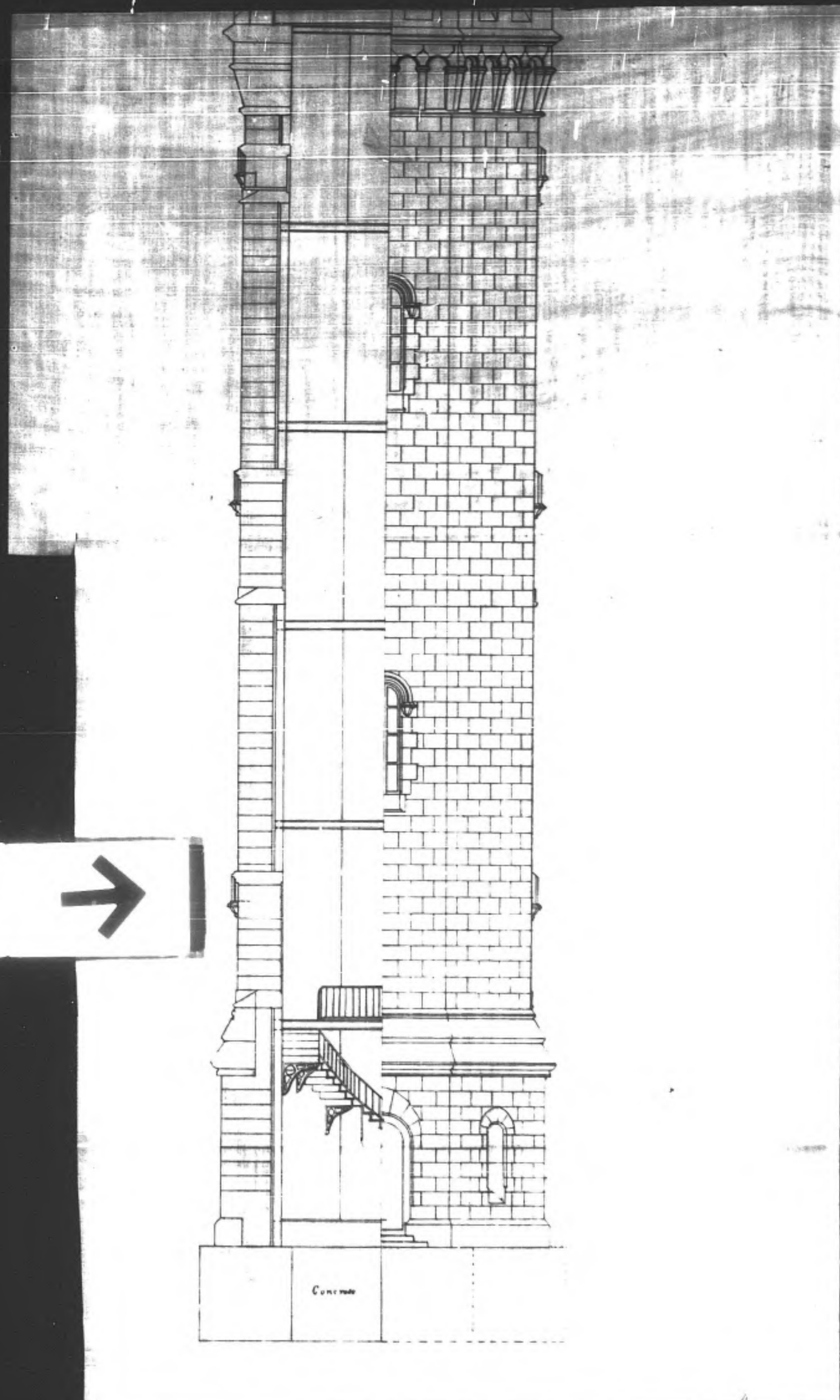




TANK TOWER



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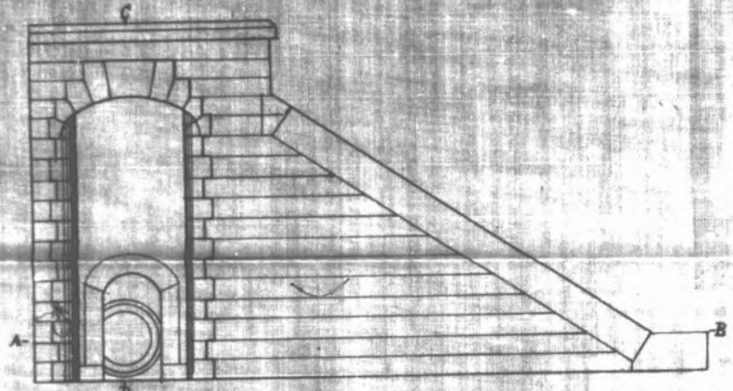
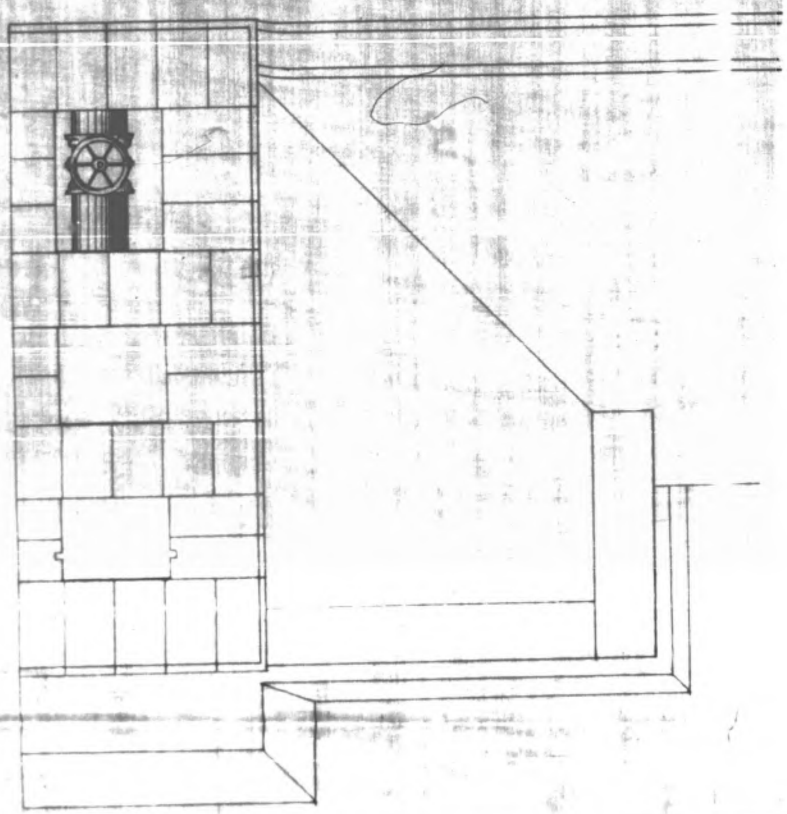
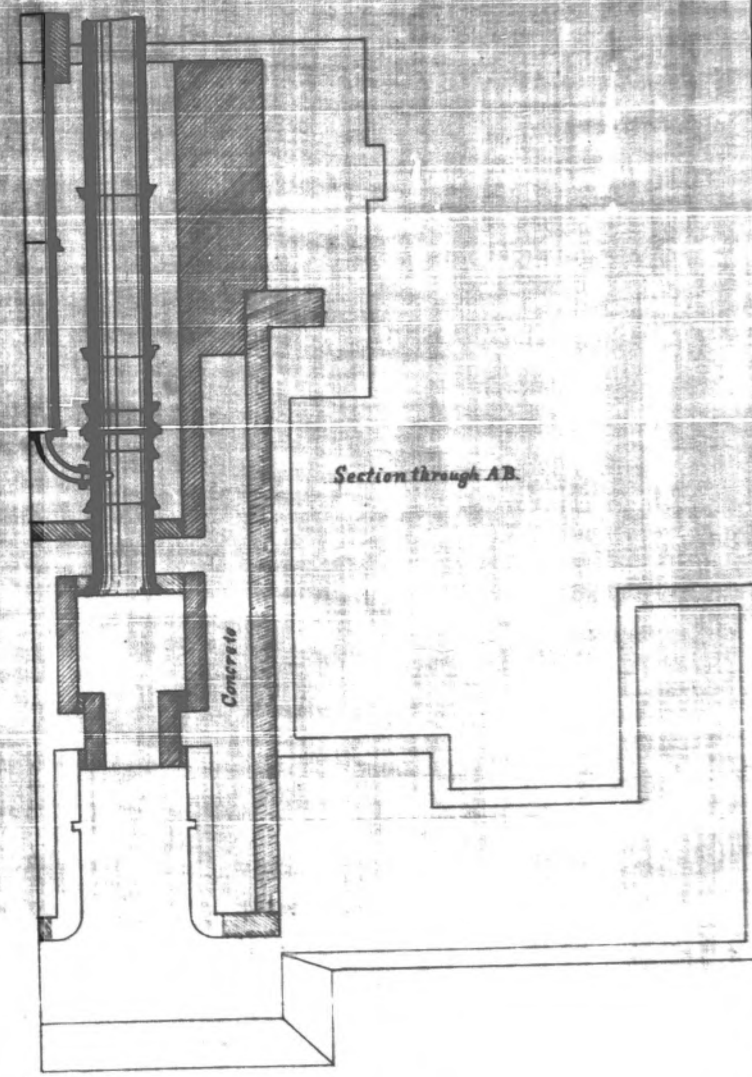


Half Elevation and Plan at Effluent Gate House





Section through A.B.

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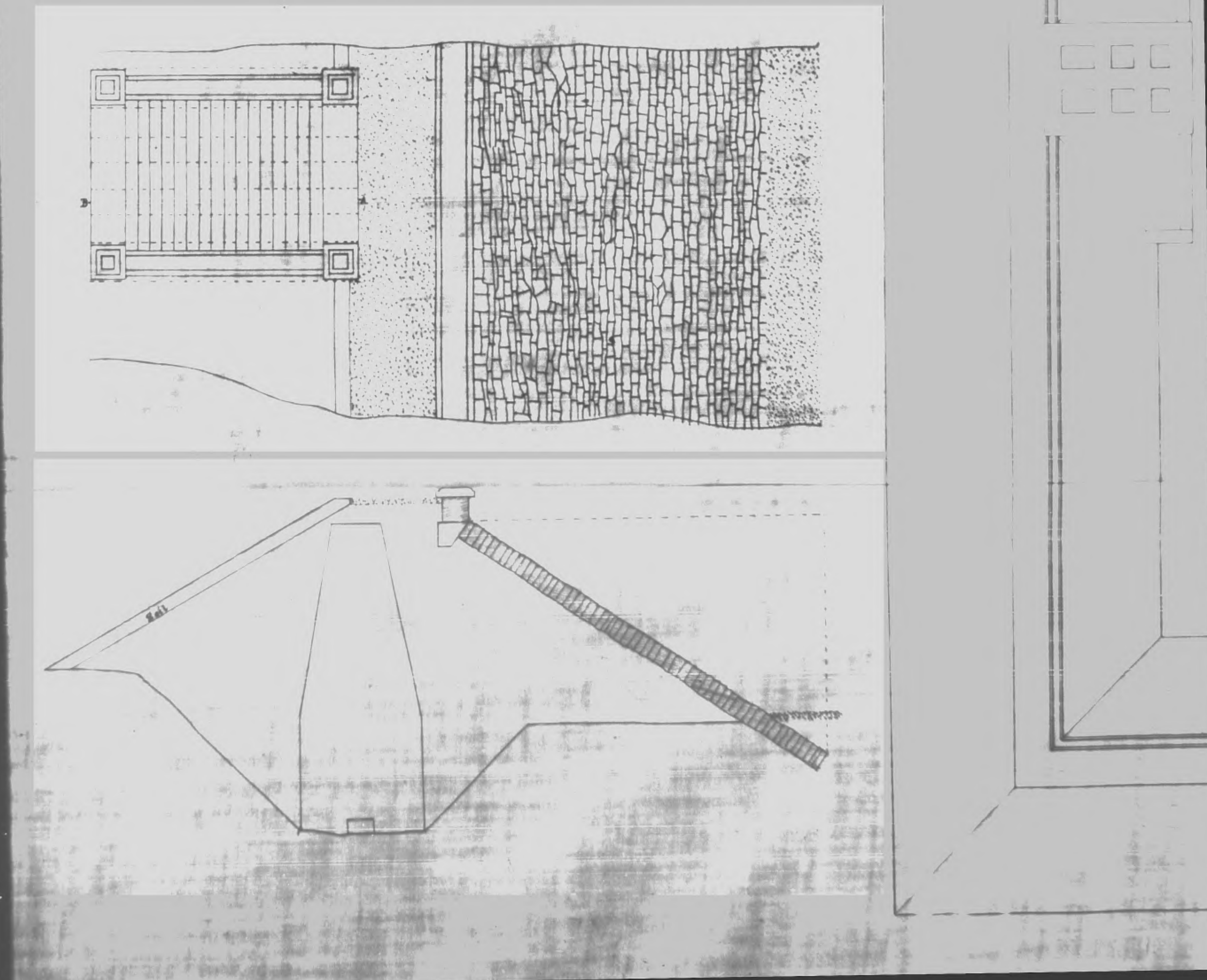

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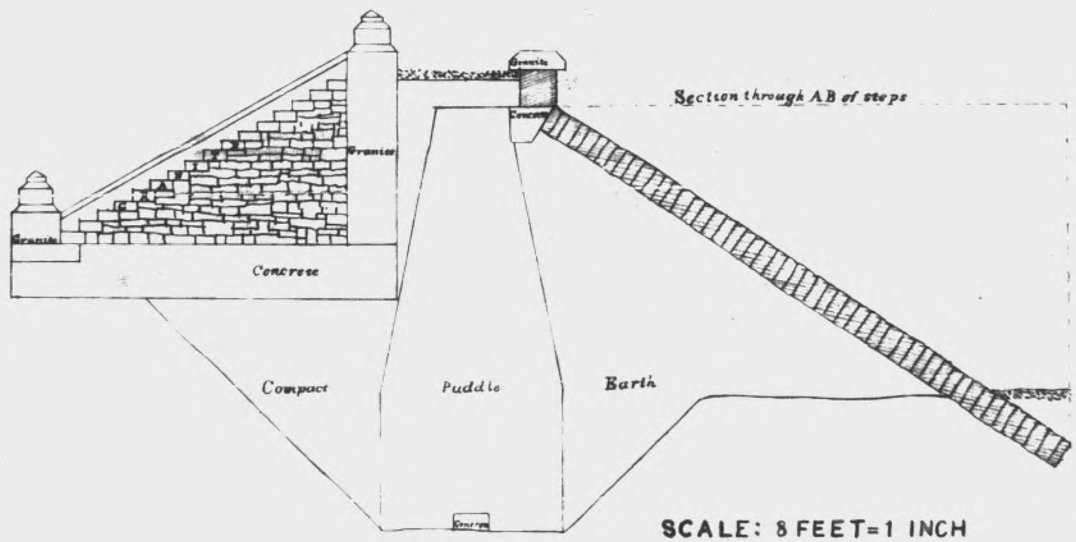

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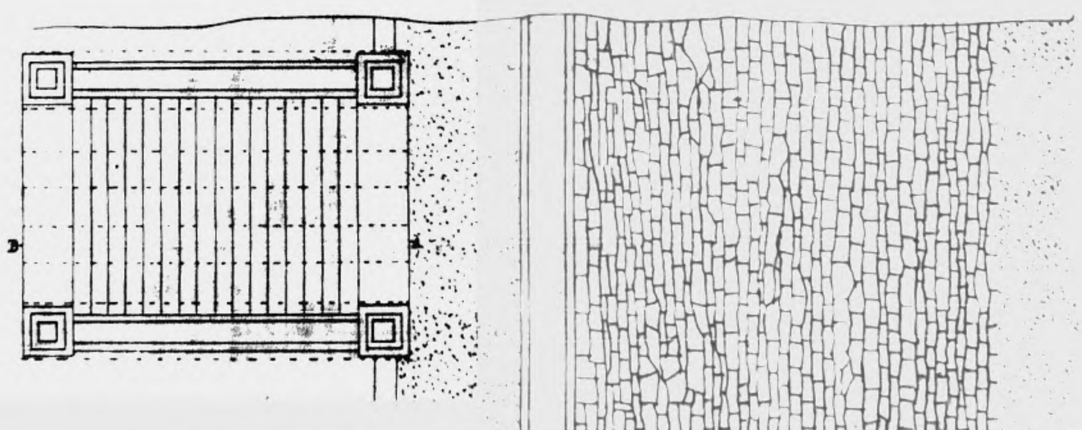

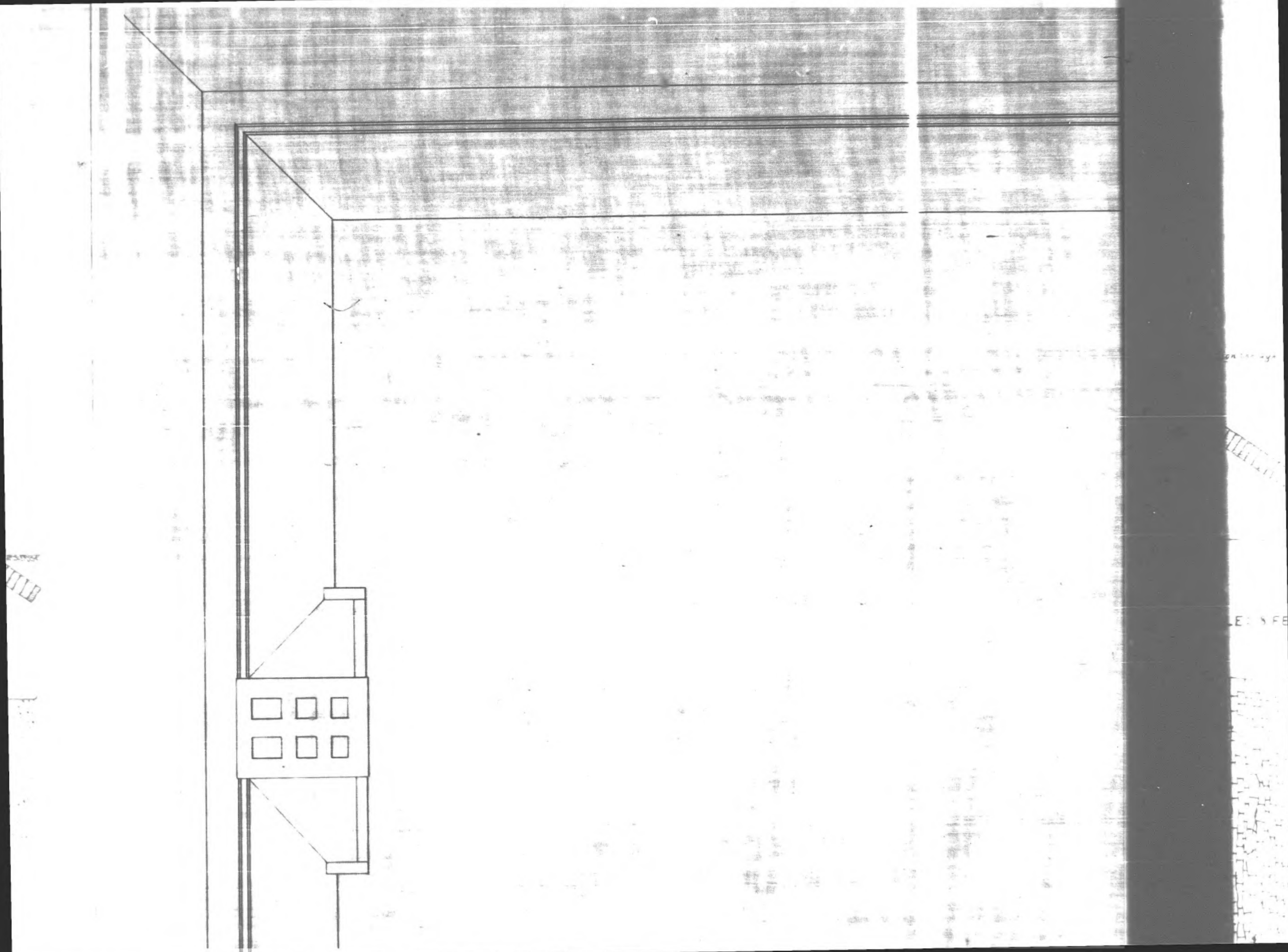

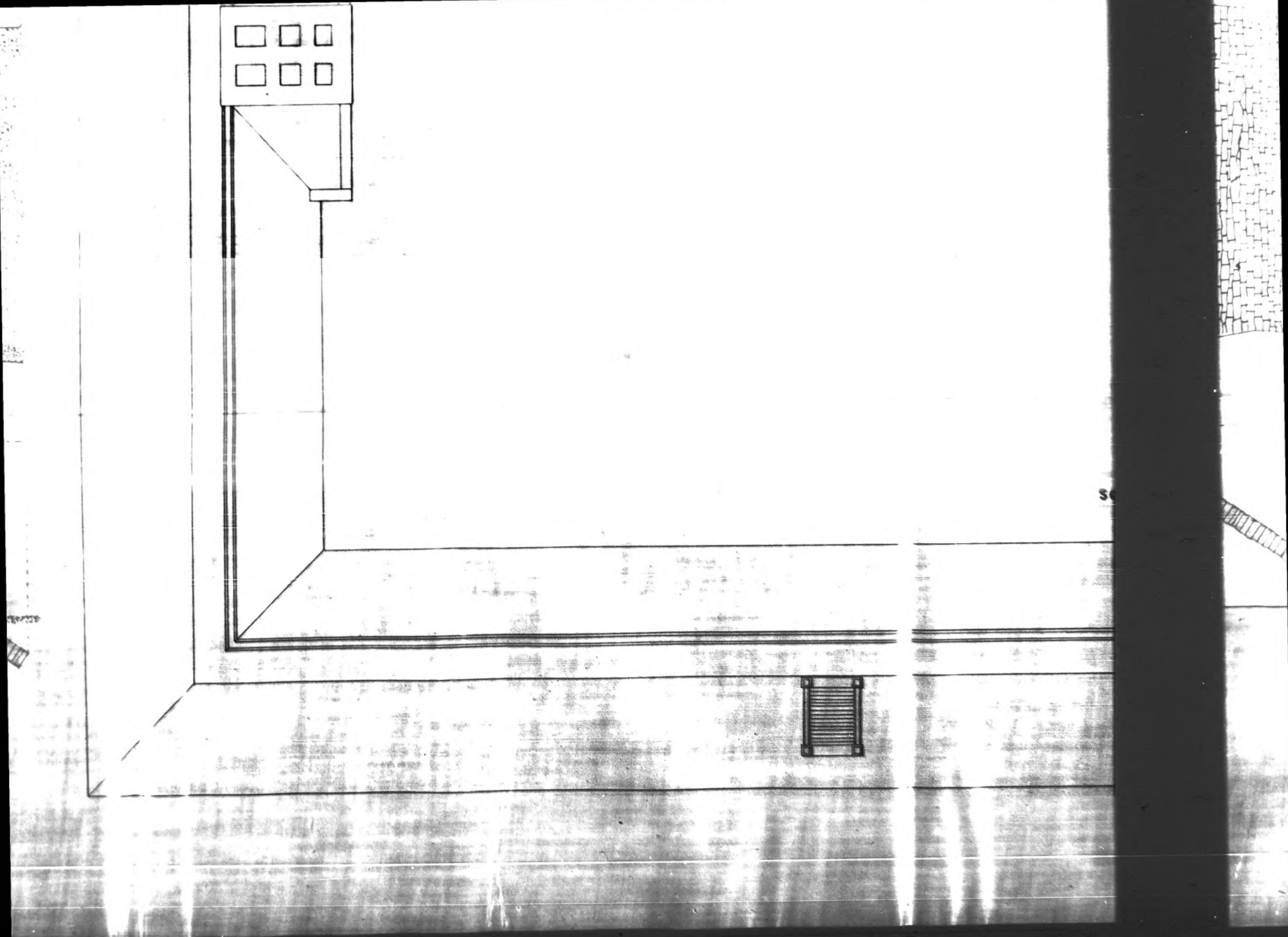

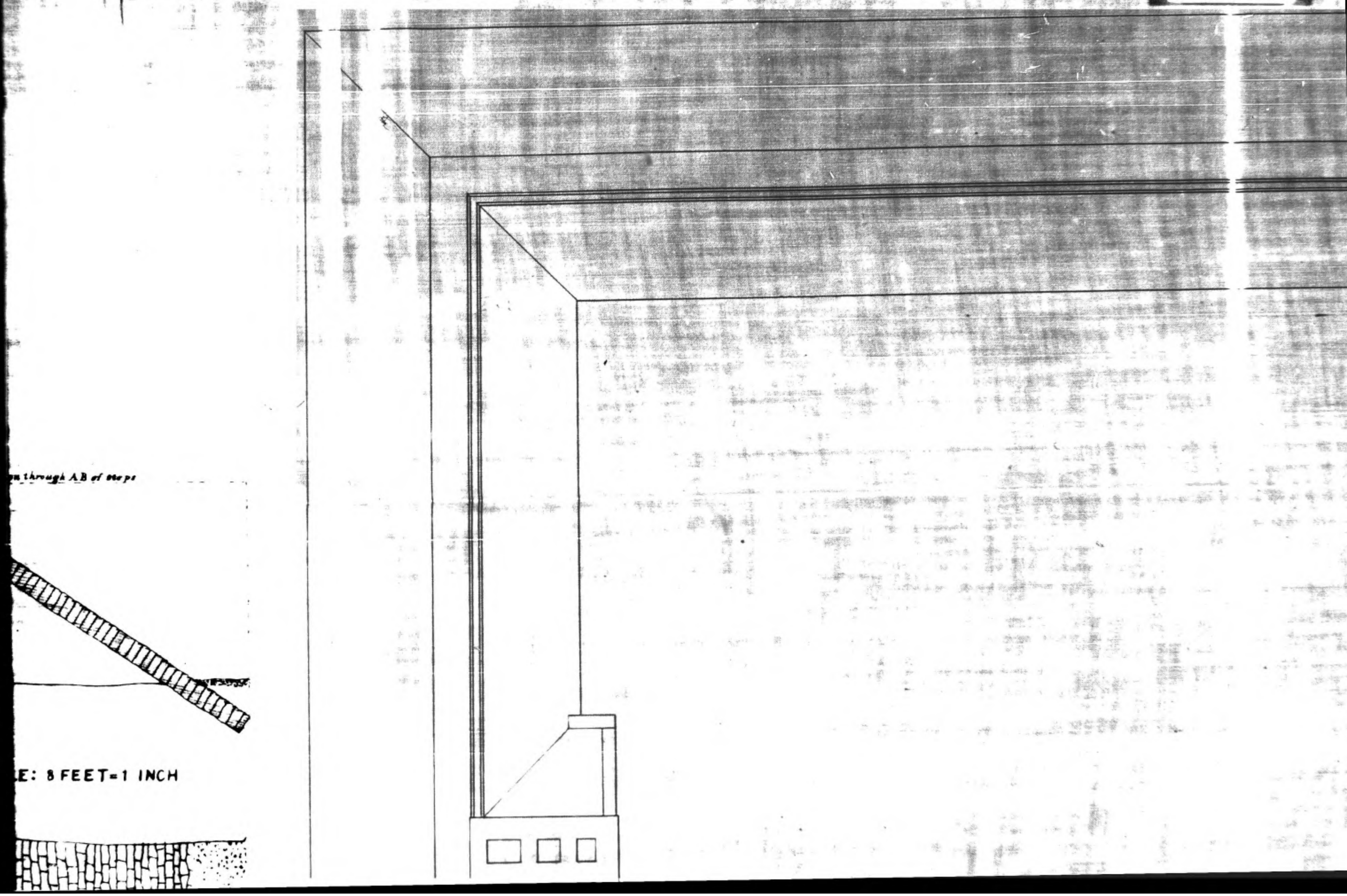
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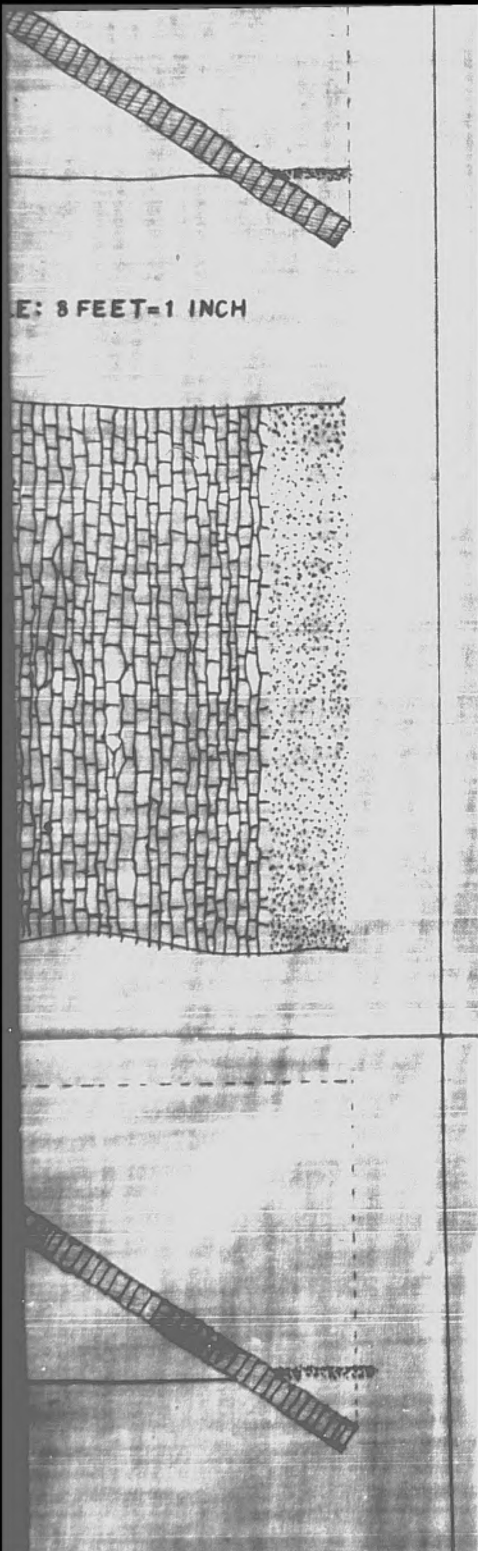
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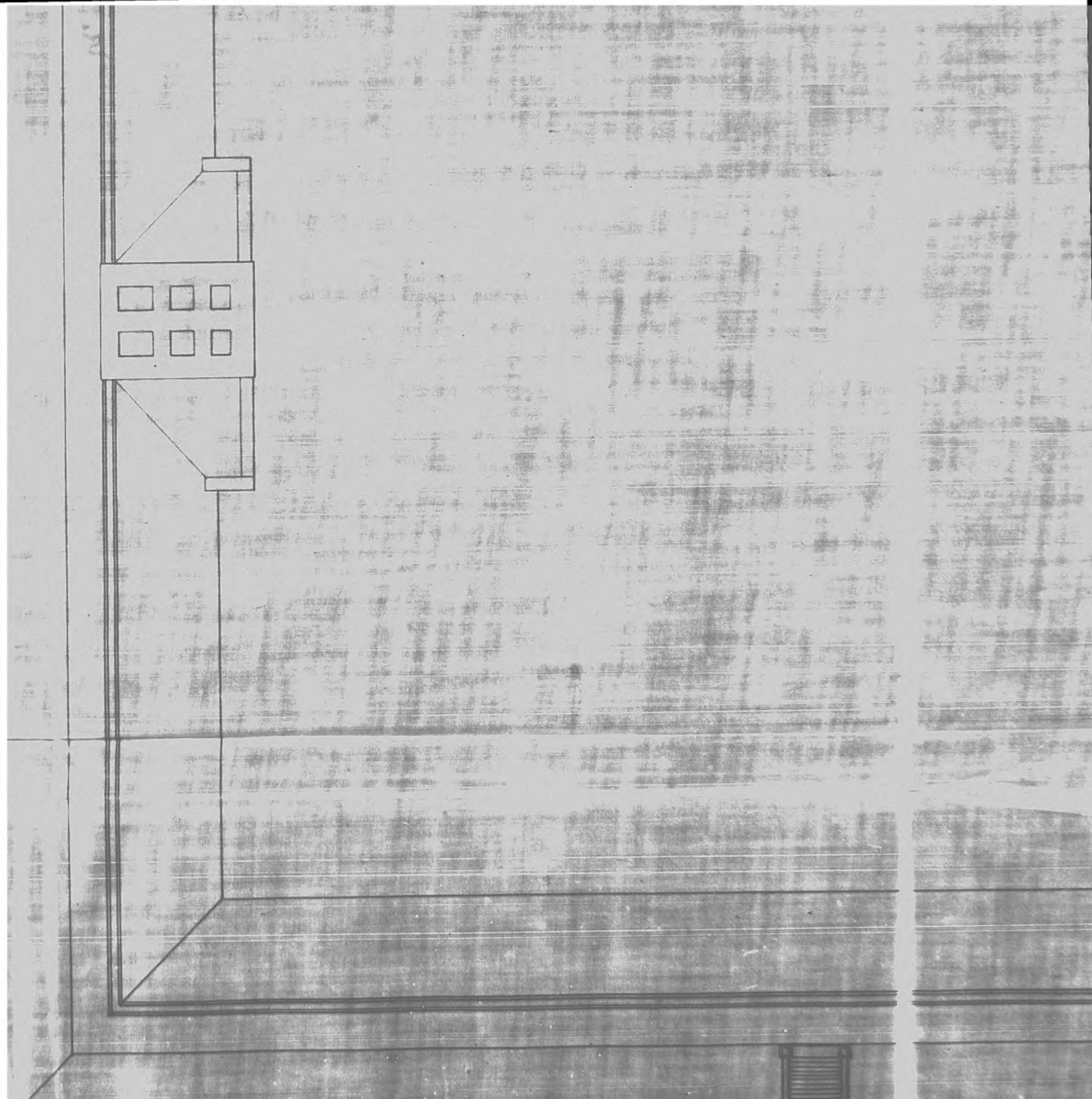

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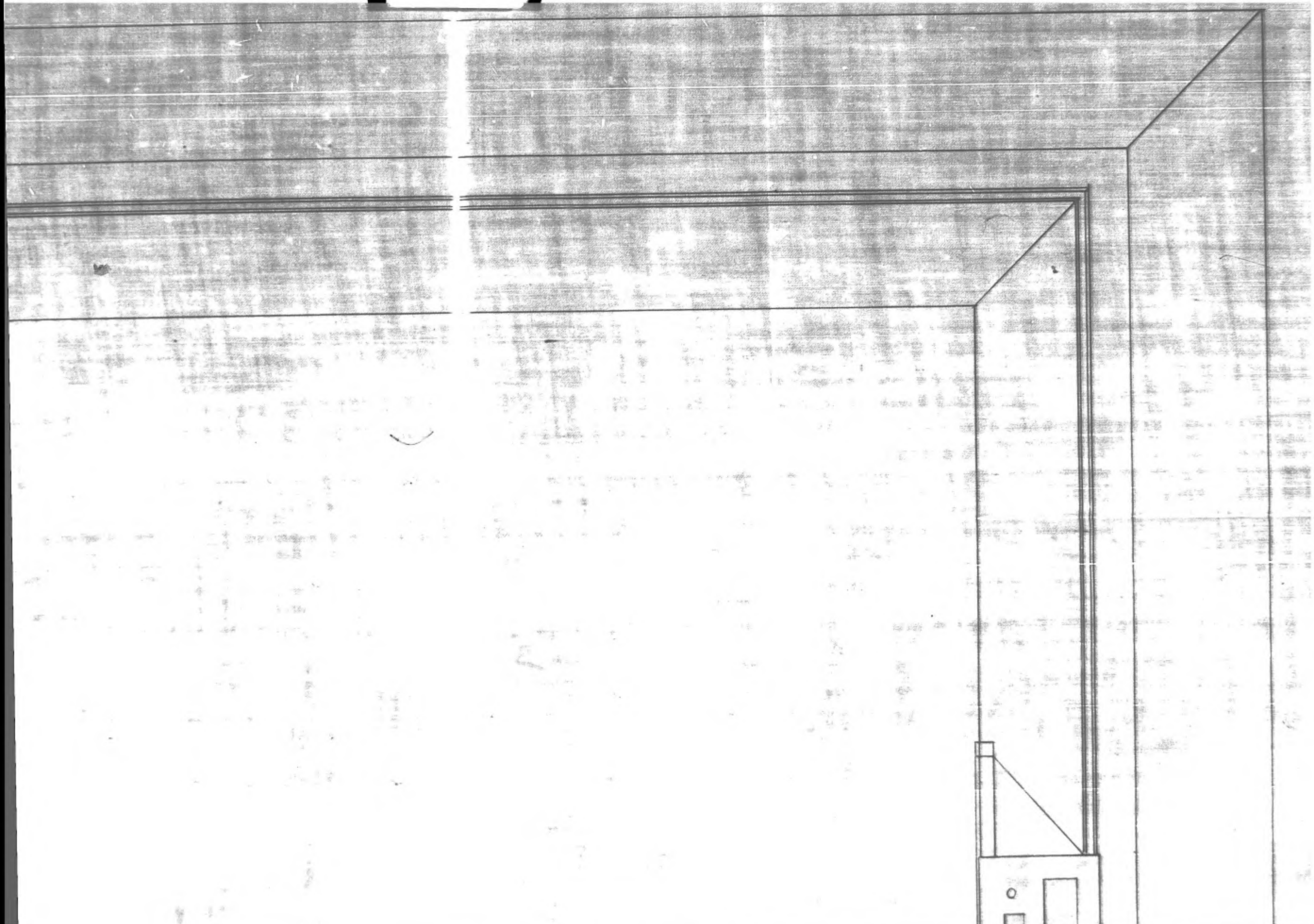

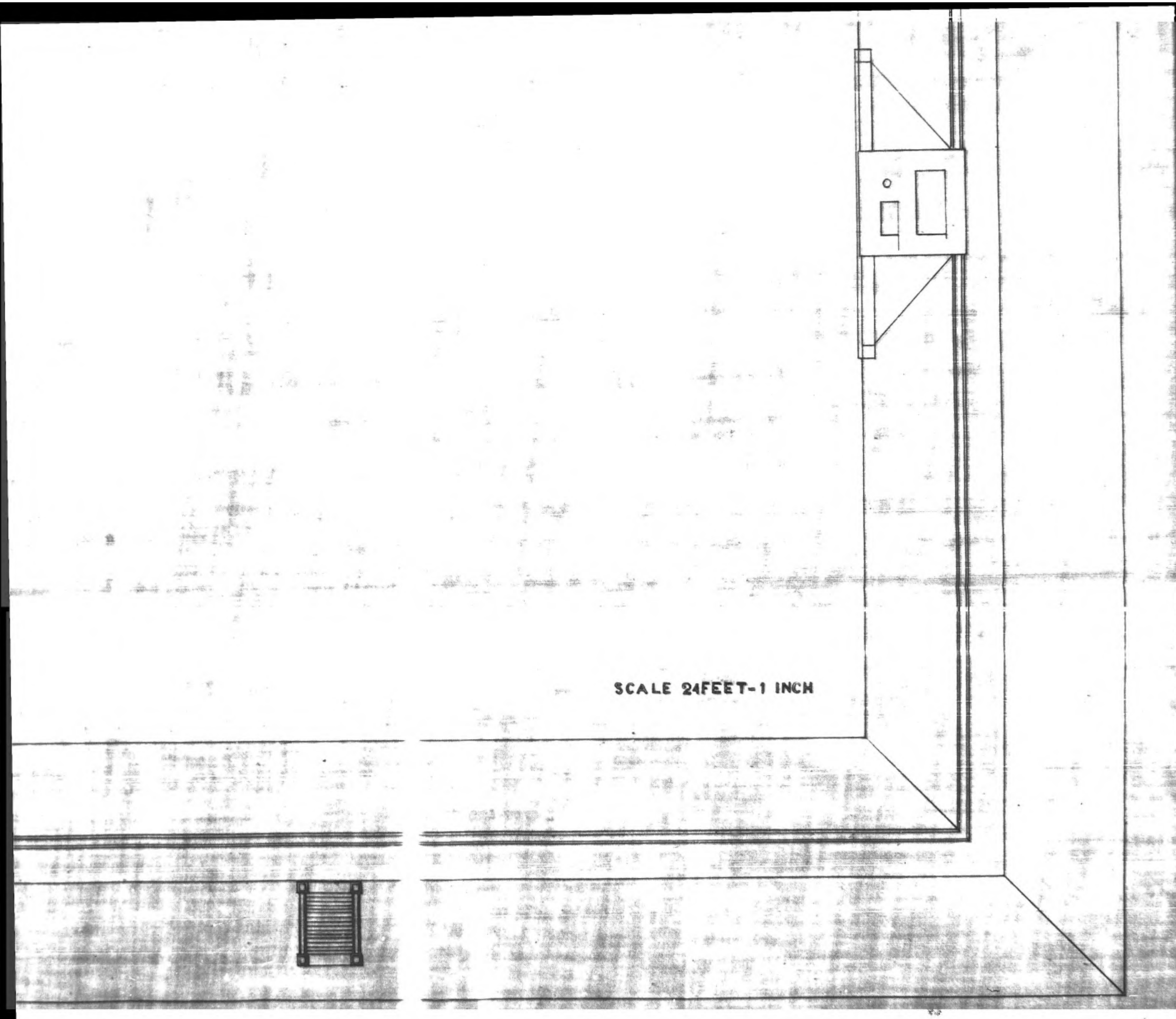
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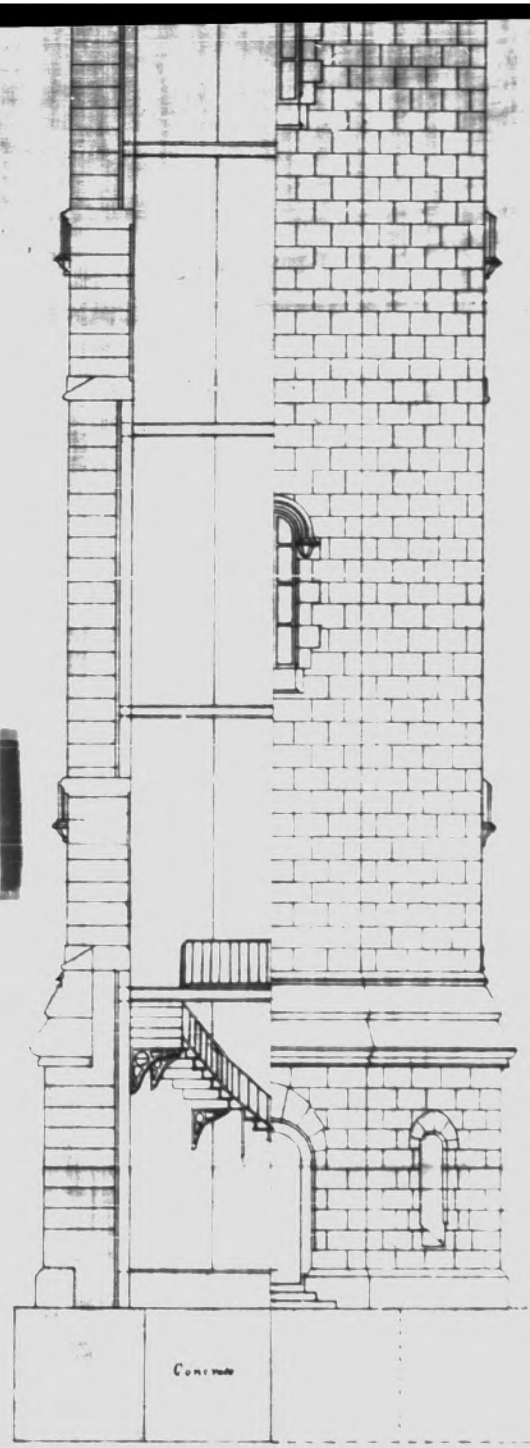
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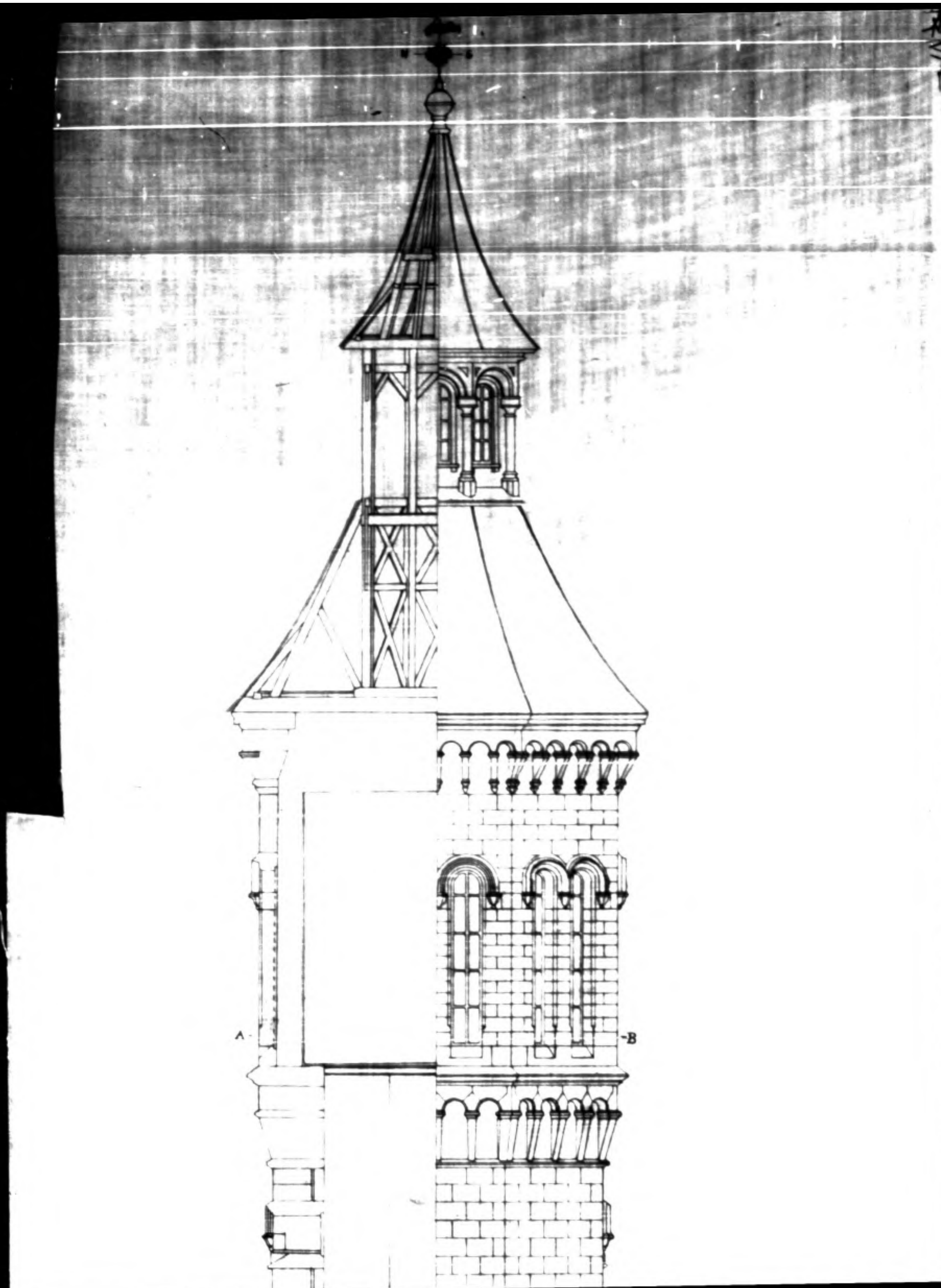
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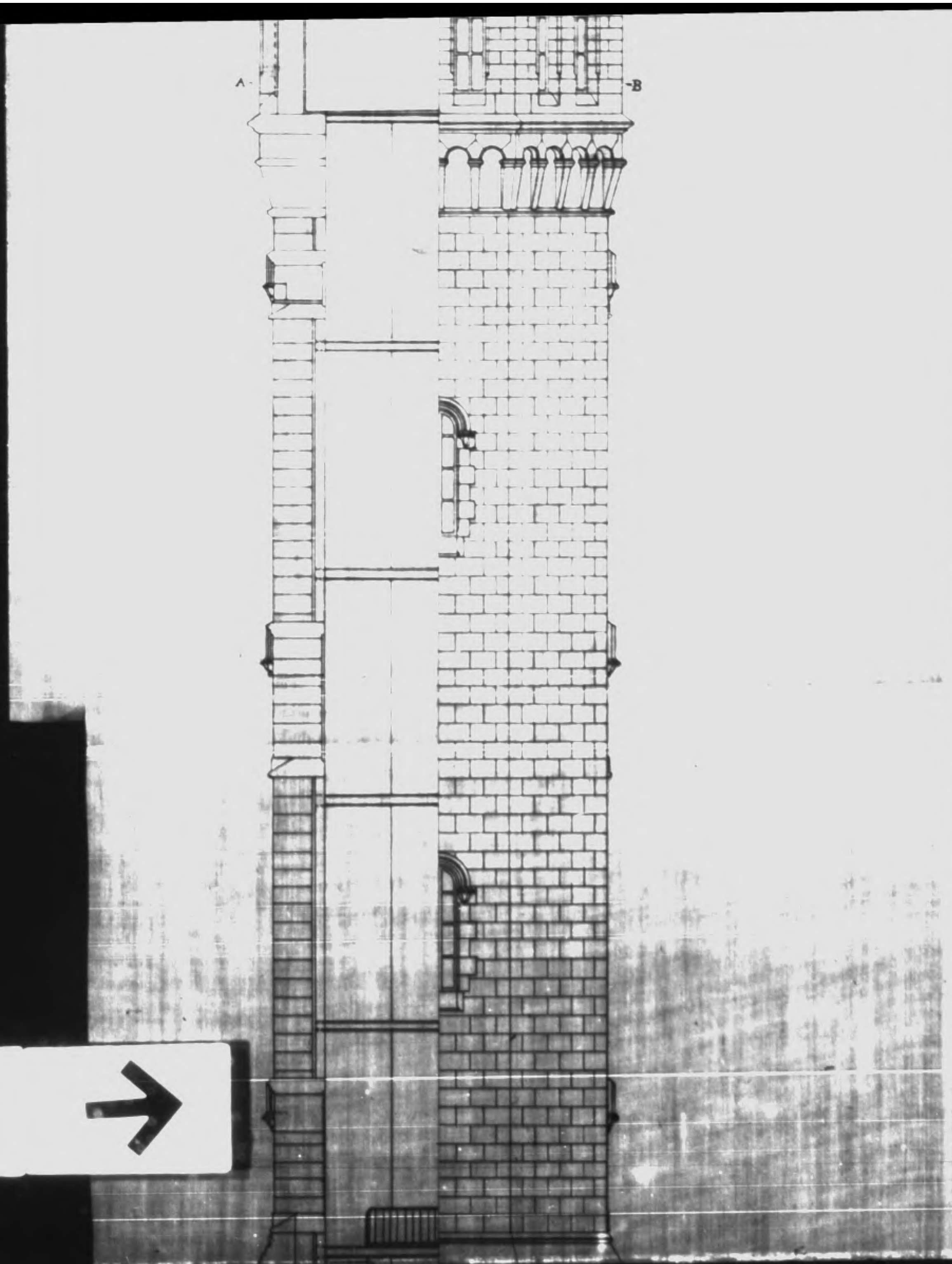

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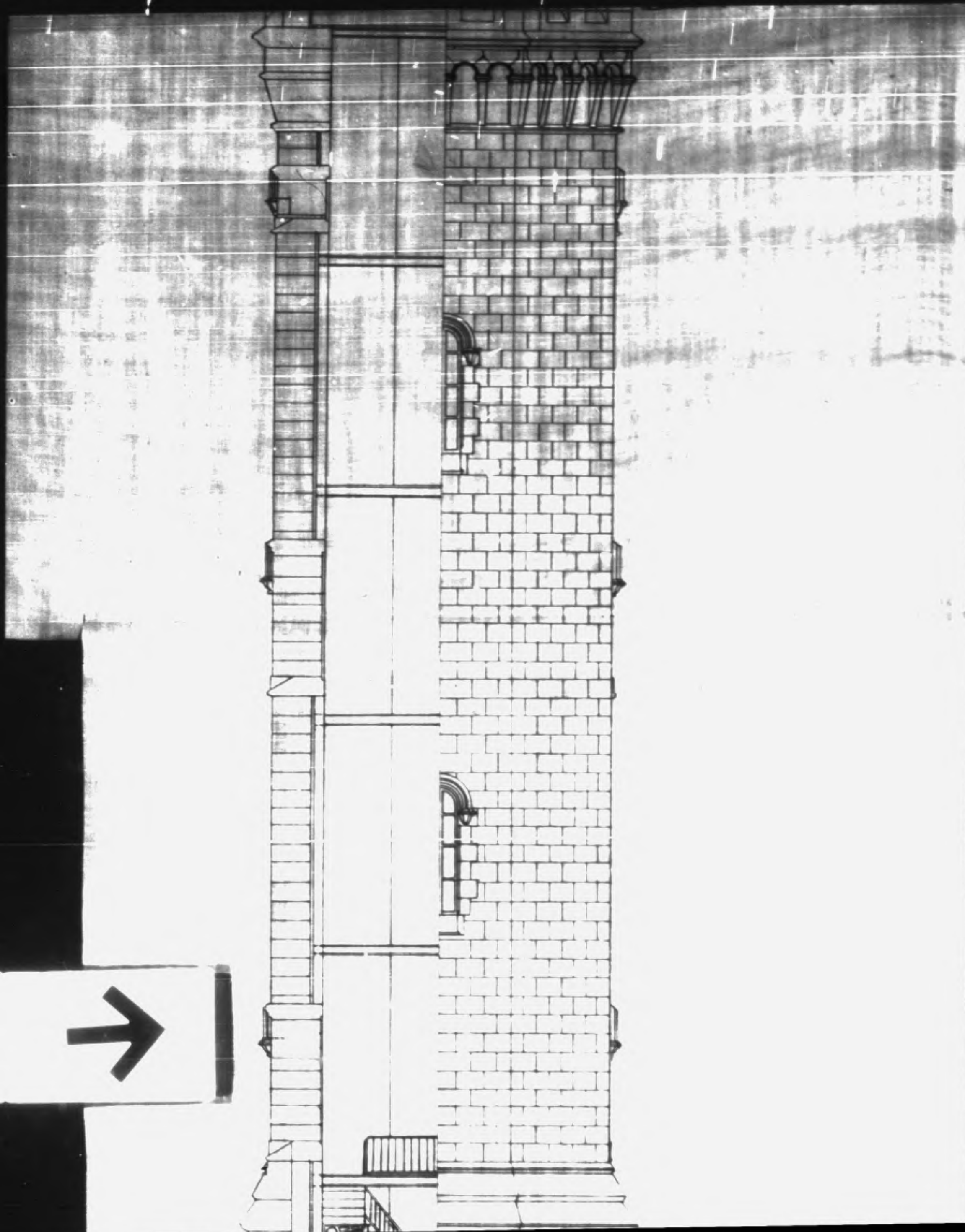

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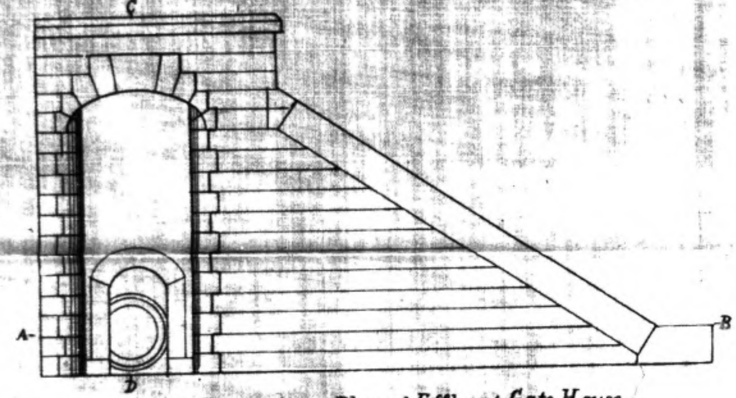
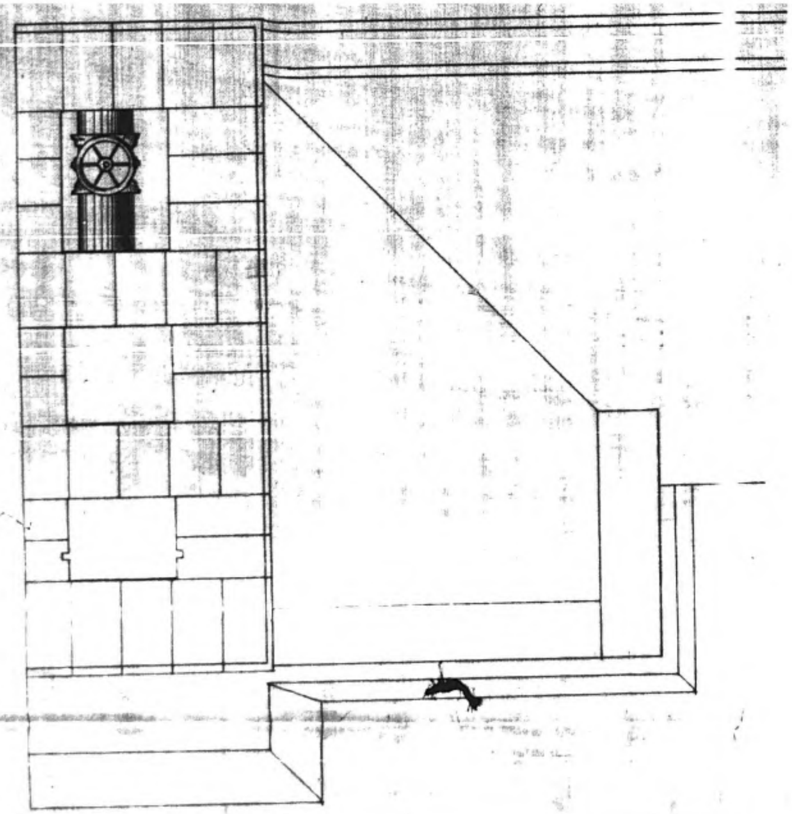
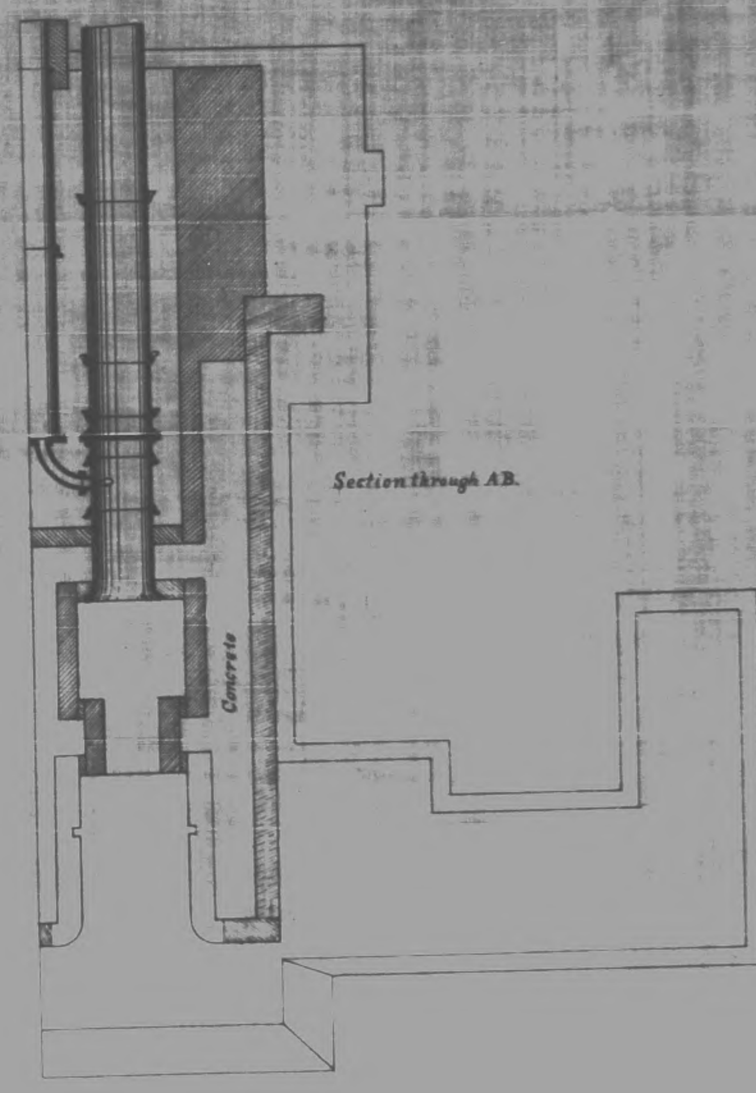
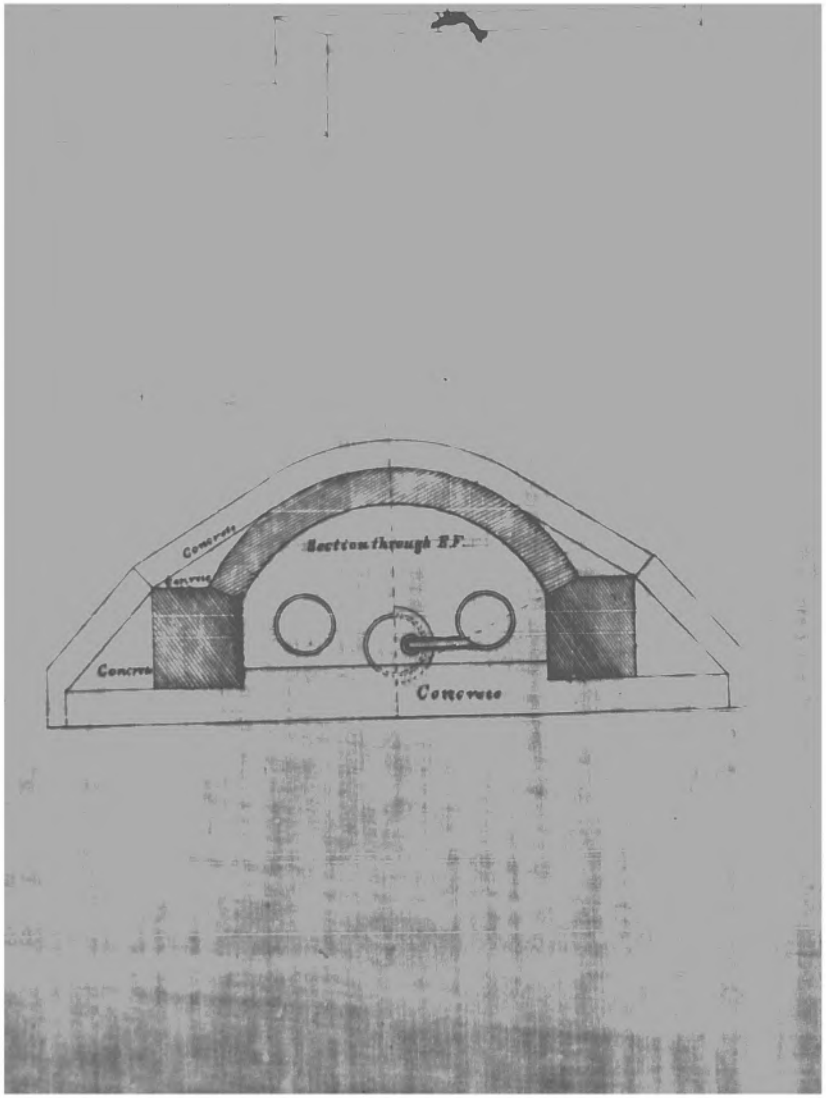


Half Elevation and Plan of Effluent Gate House







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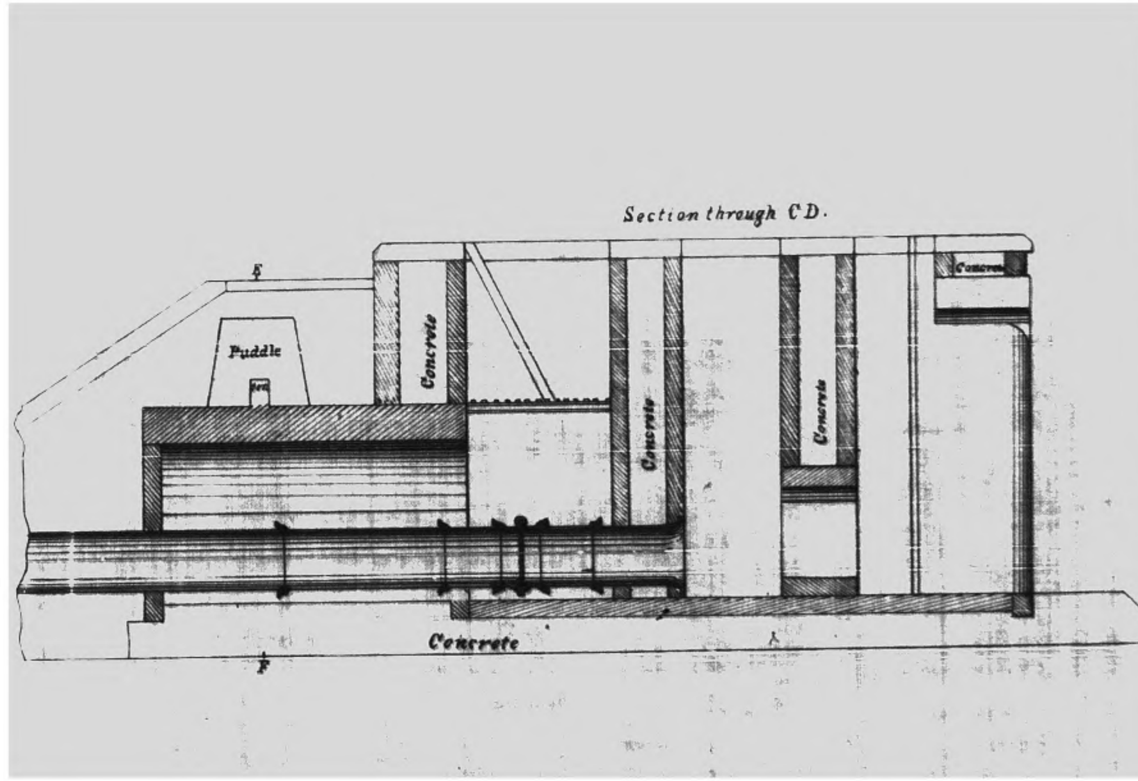

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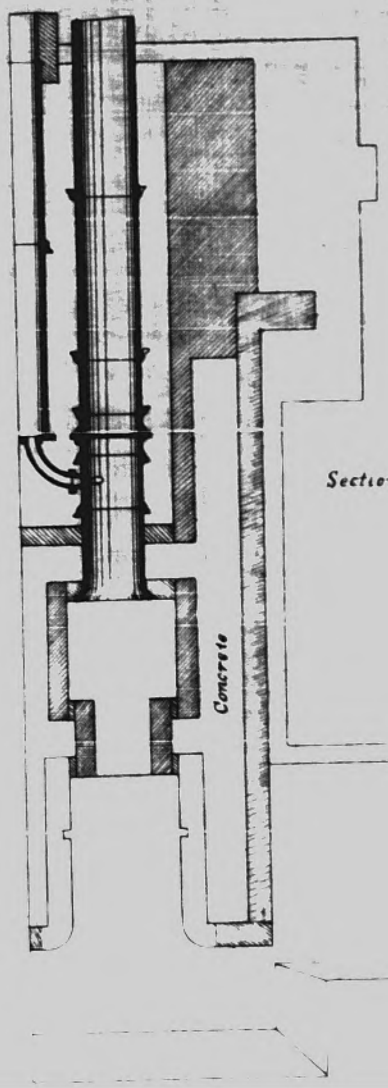
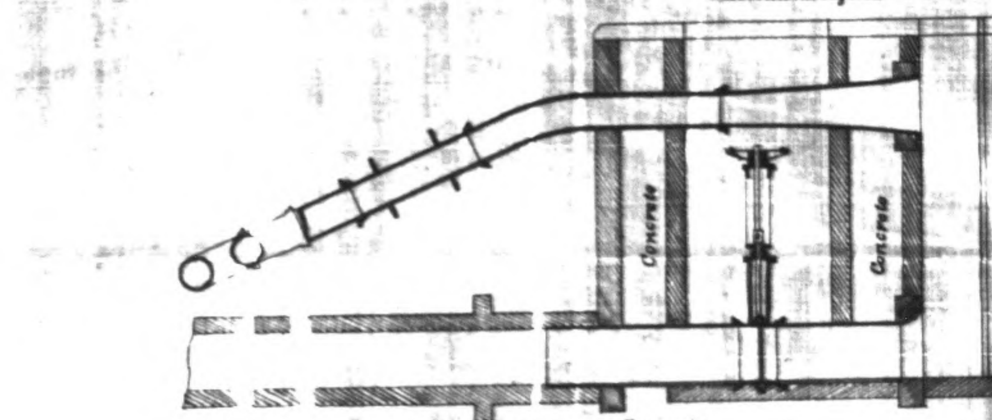
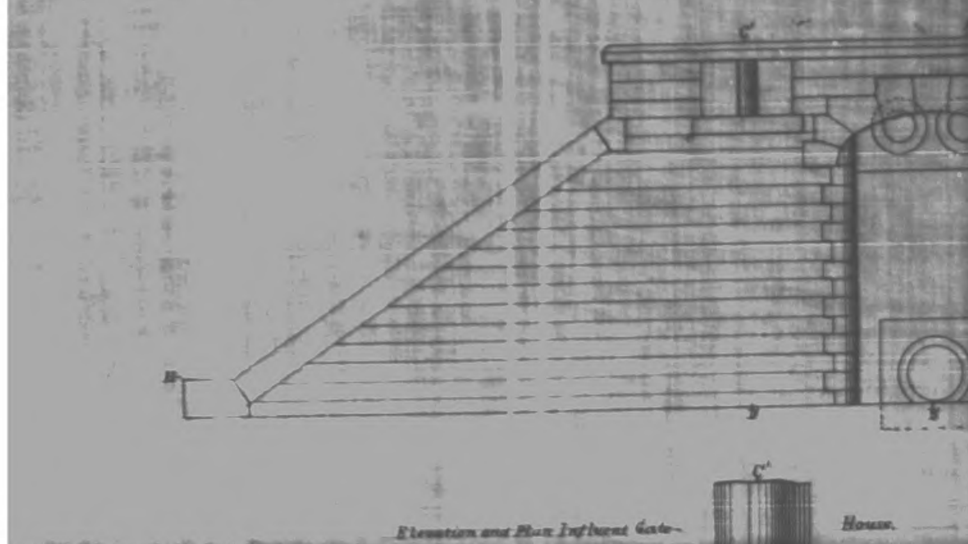
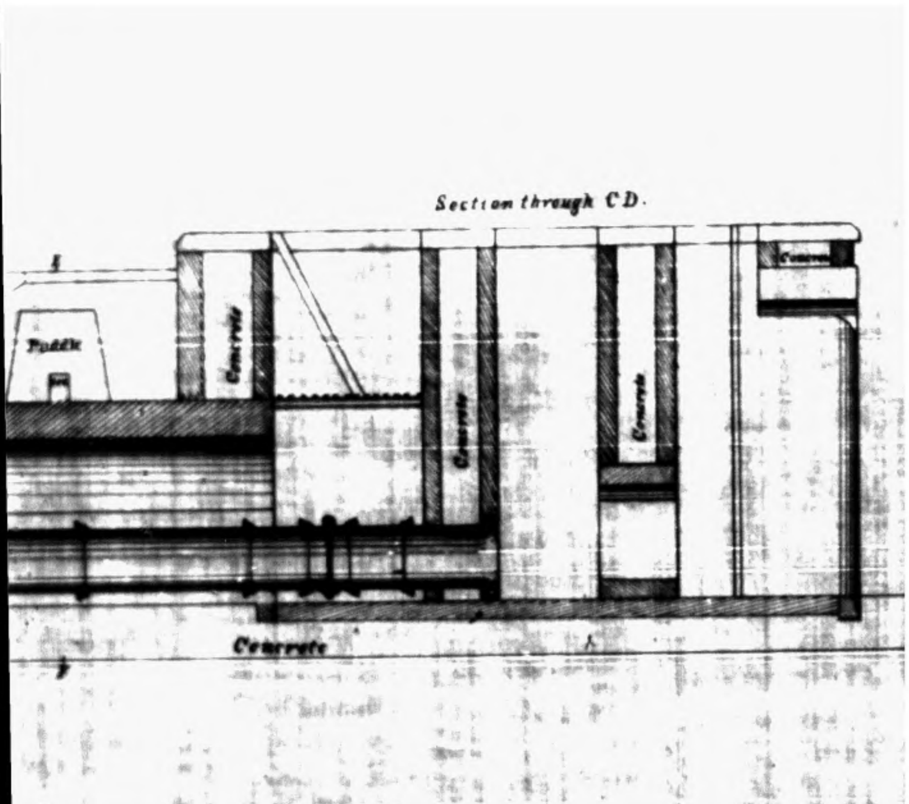


Section through A B.





Elevation and Plan Influent Gate-House.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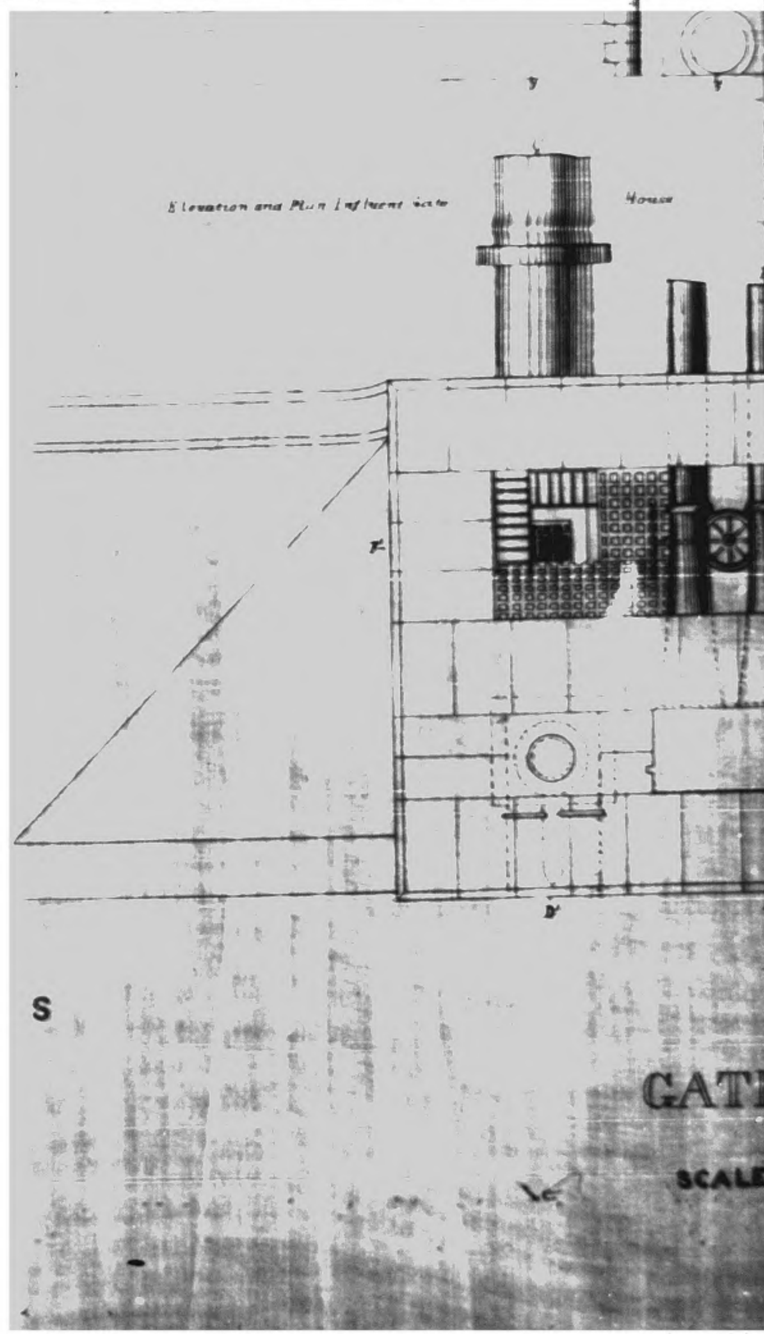
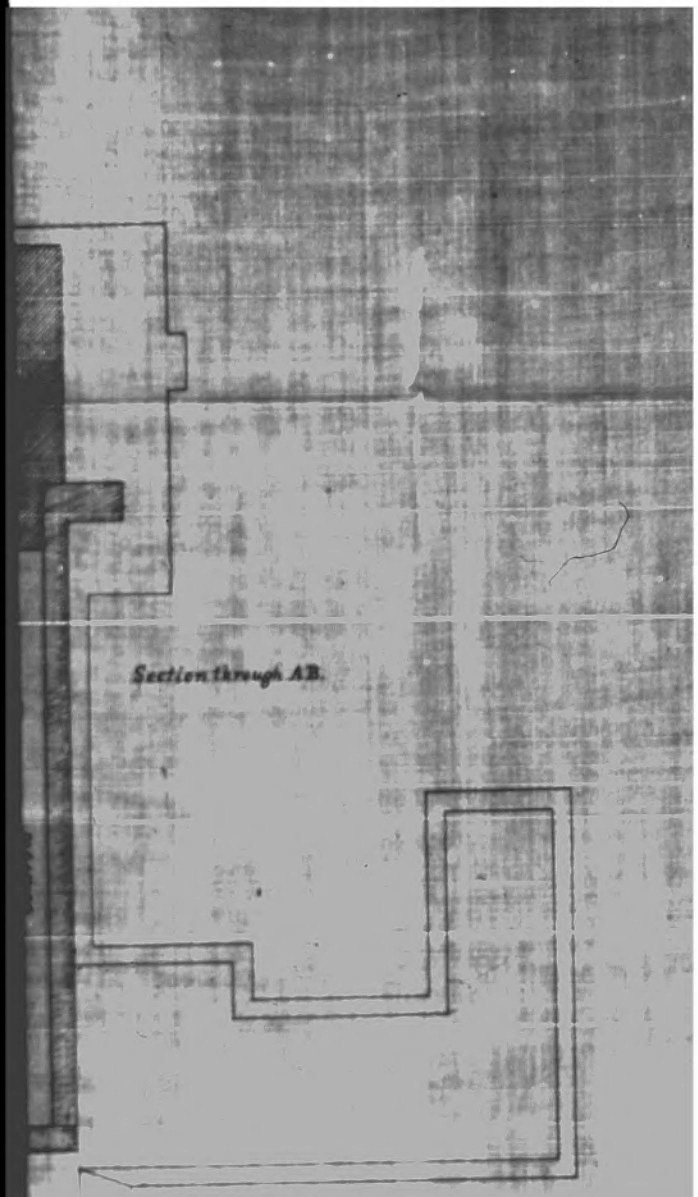
Puddle
Concrete
Concrete
Concrete
Concrete


Elevation and Plan Influent Gate House
S
GATE
SCALE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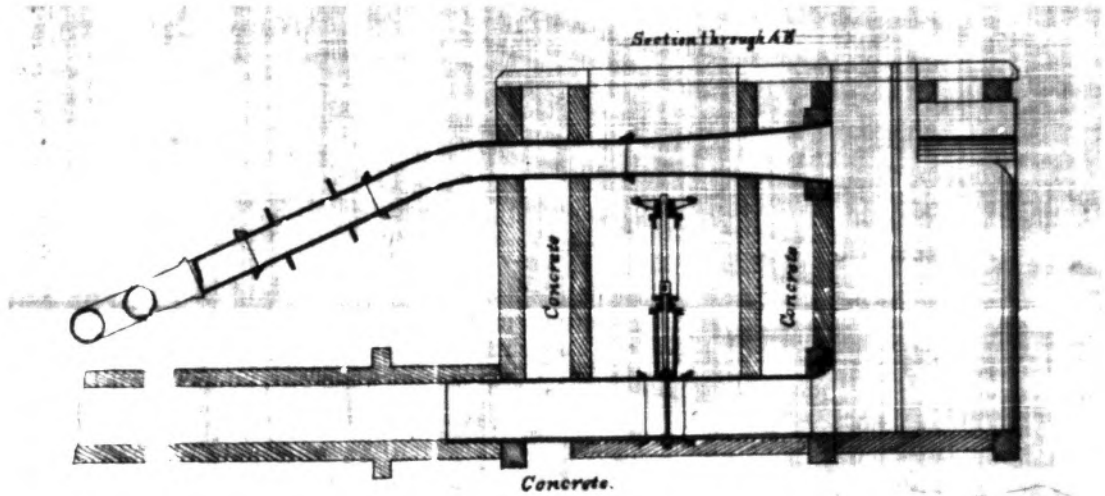
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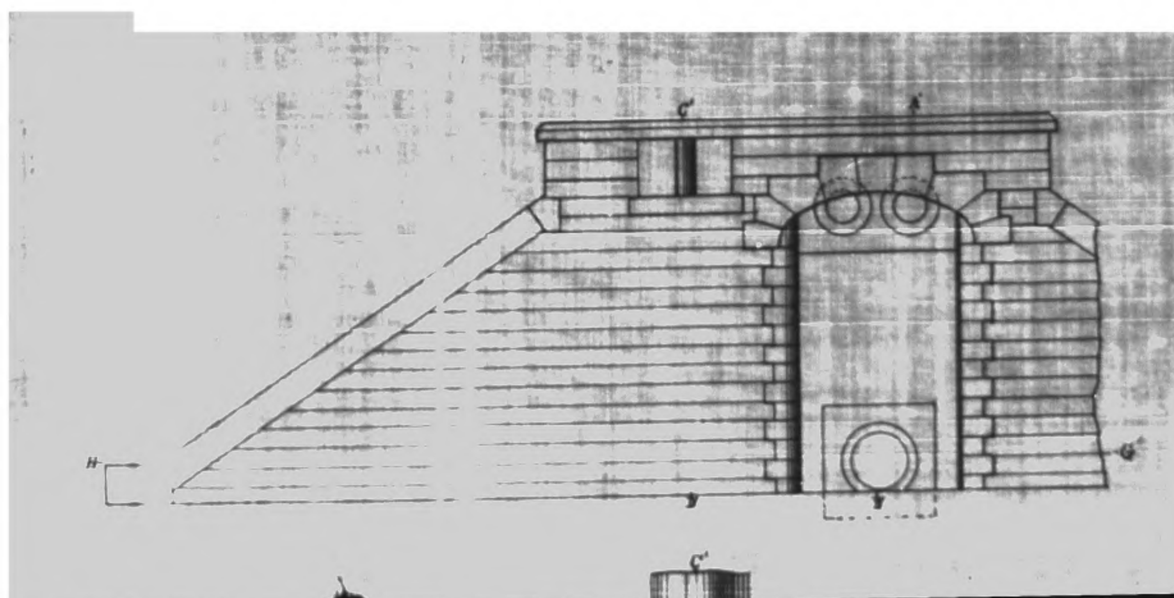
Concrete
Concrete
Concrete.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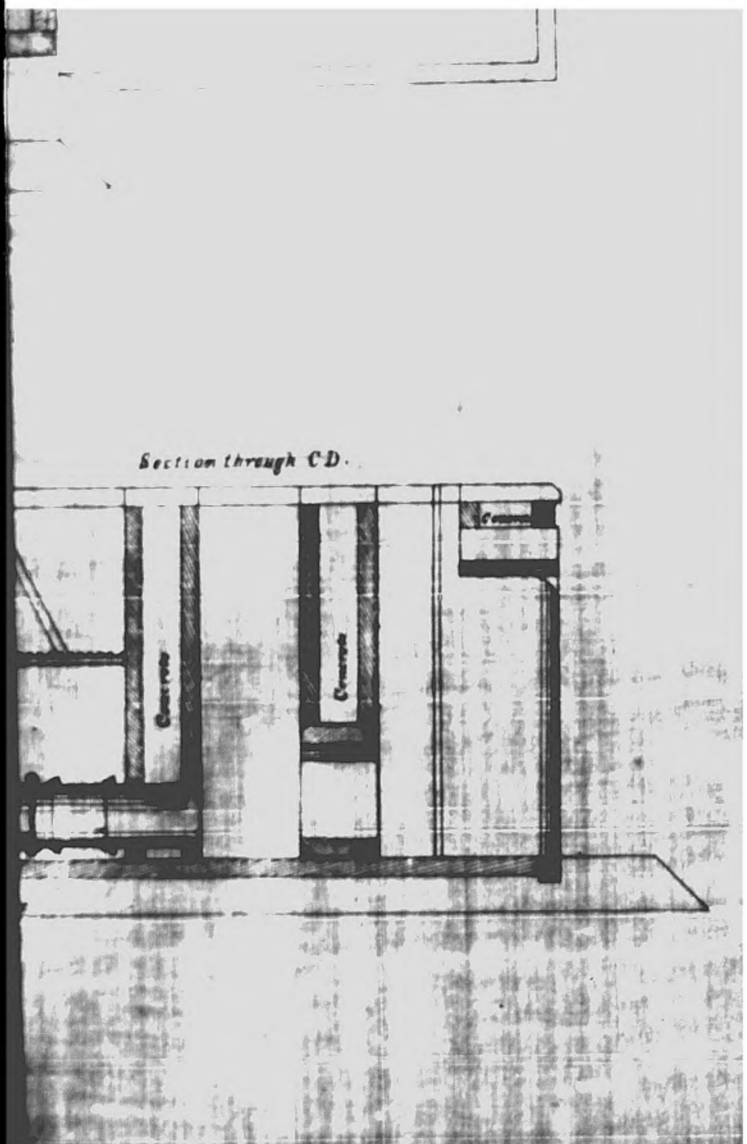
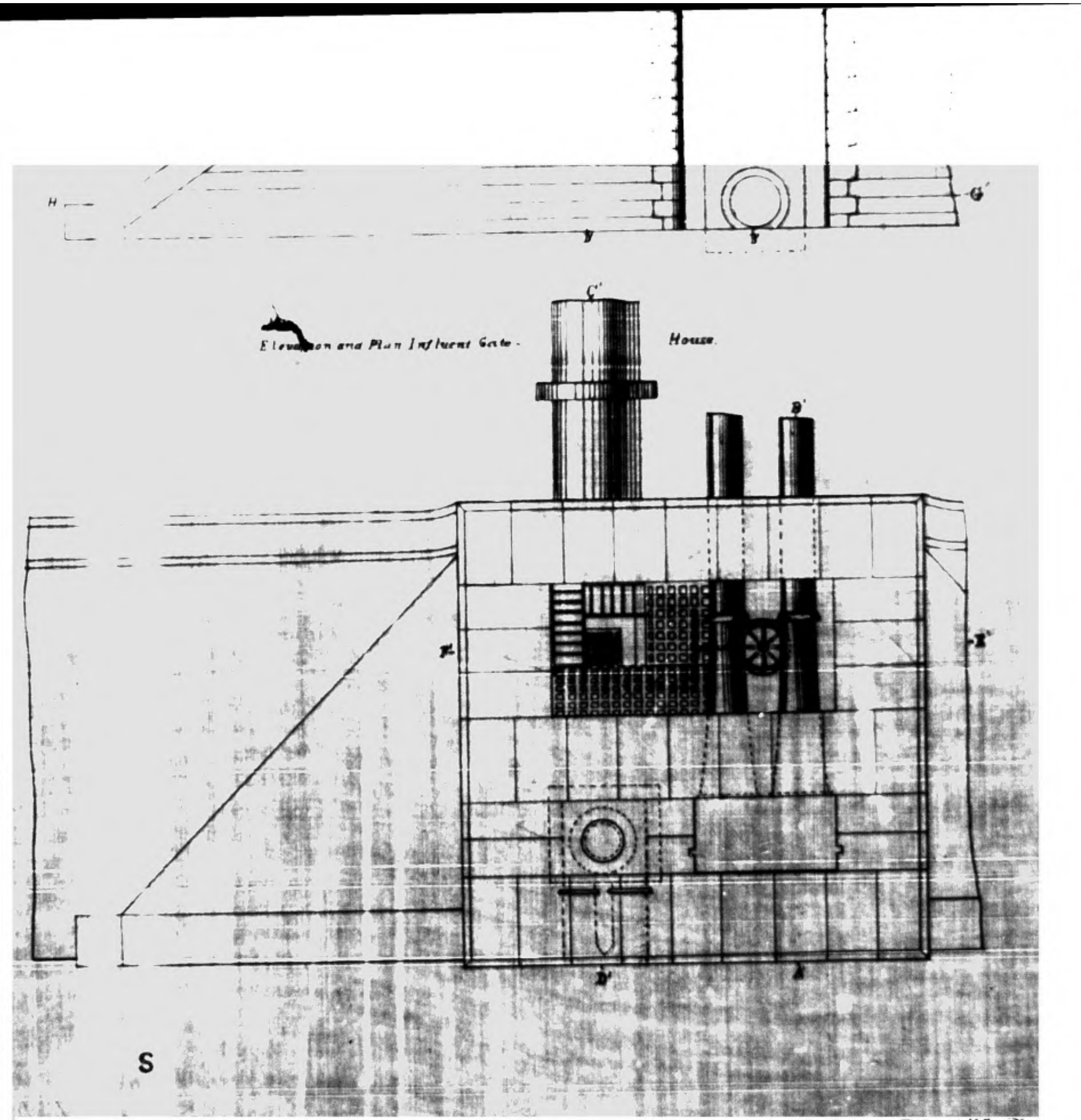
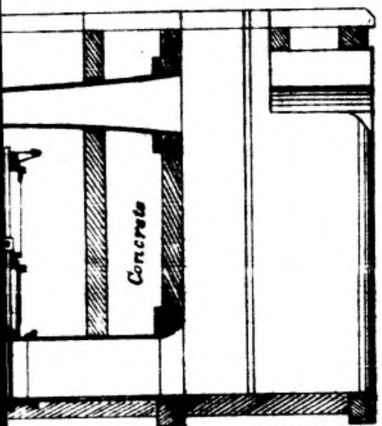


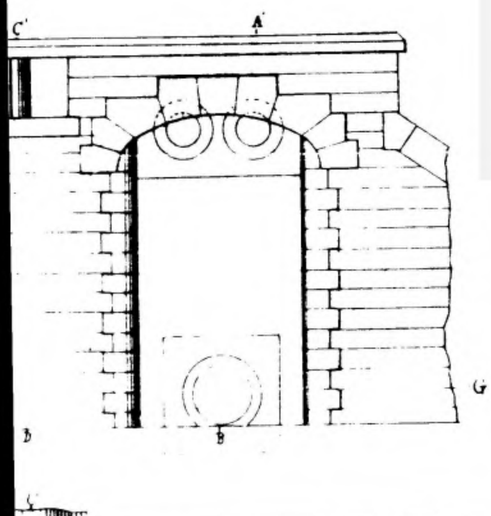


GATE HOUSES

SCALE: 8 FEET-1 INCH

rtion through AB





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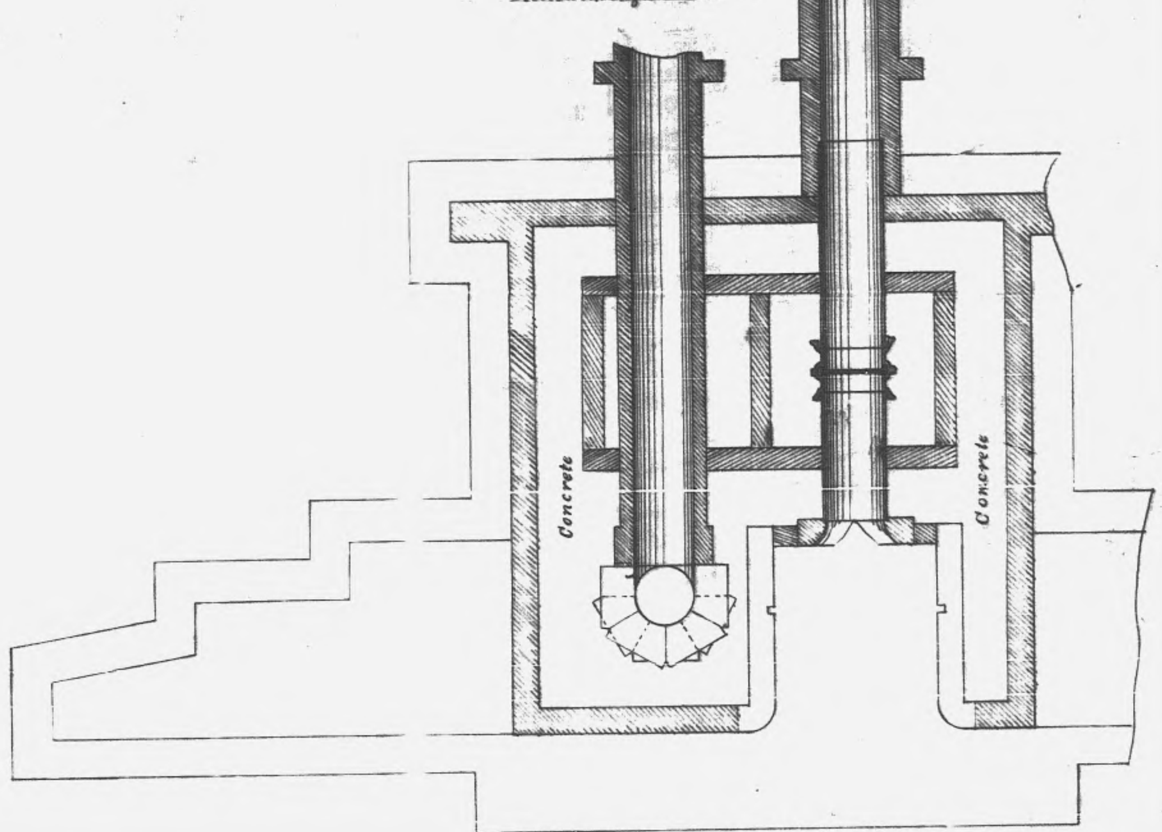
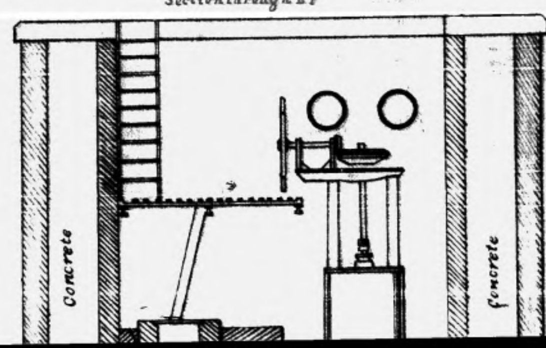
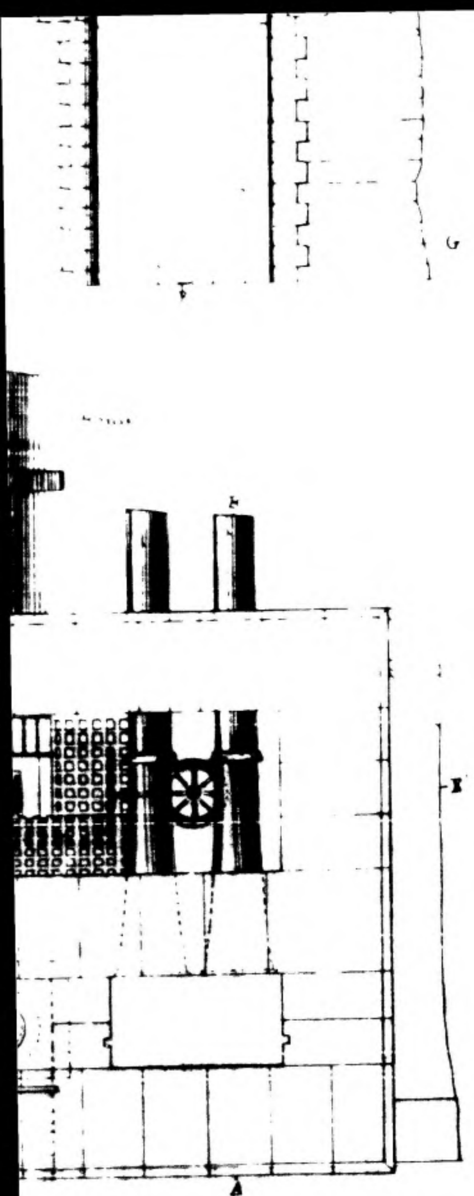
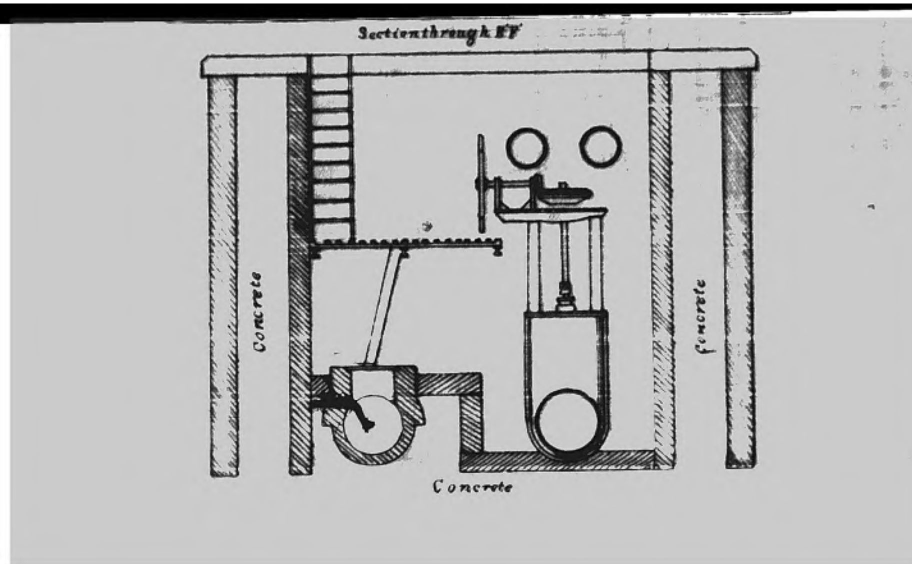
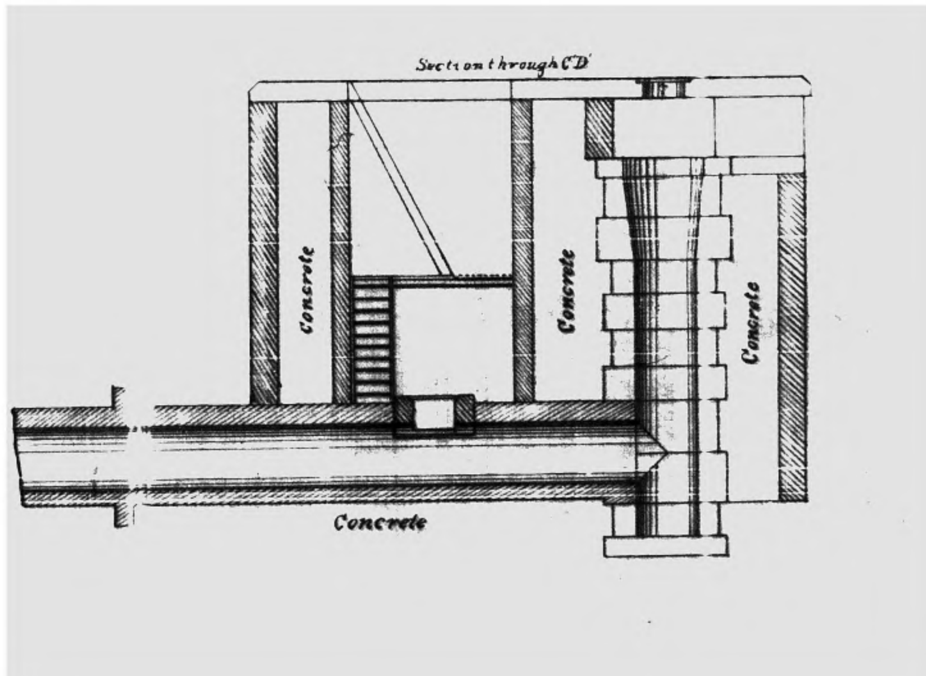


Section through EF



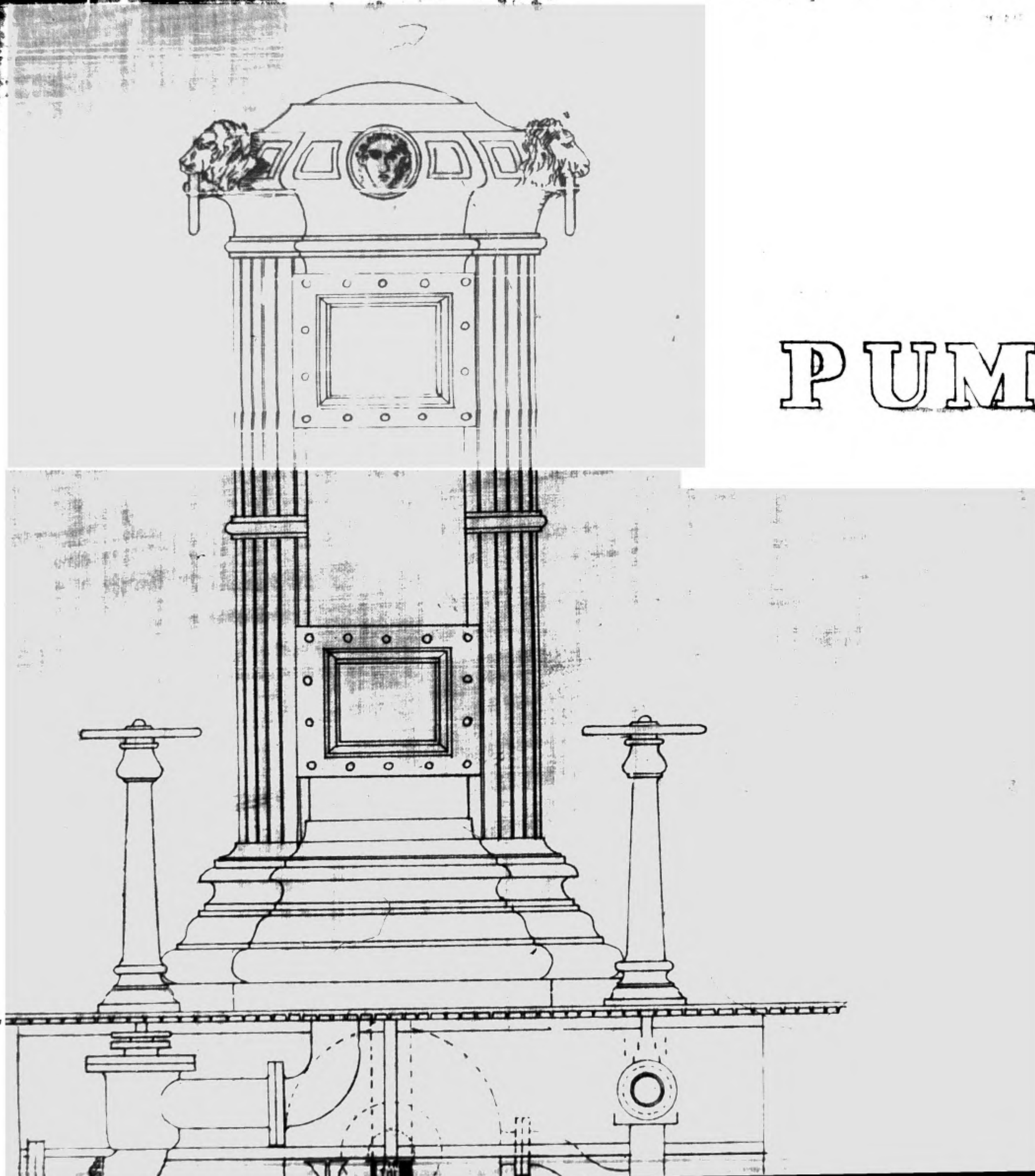




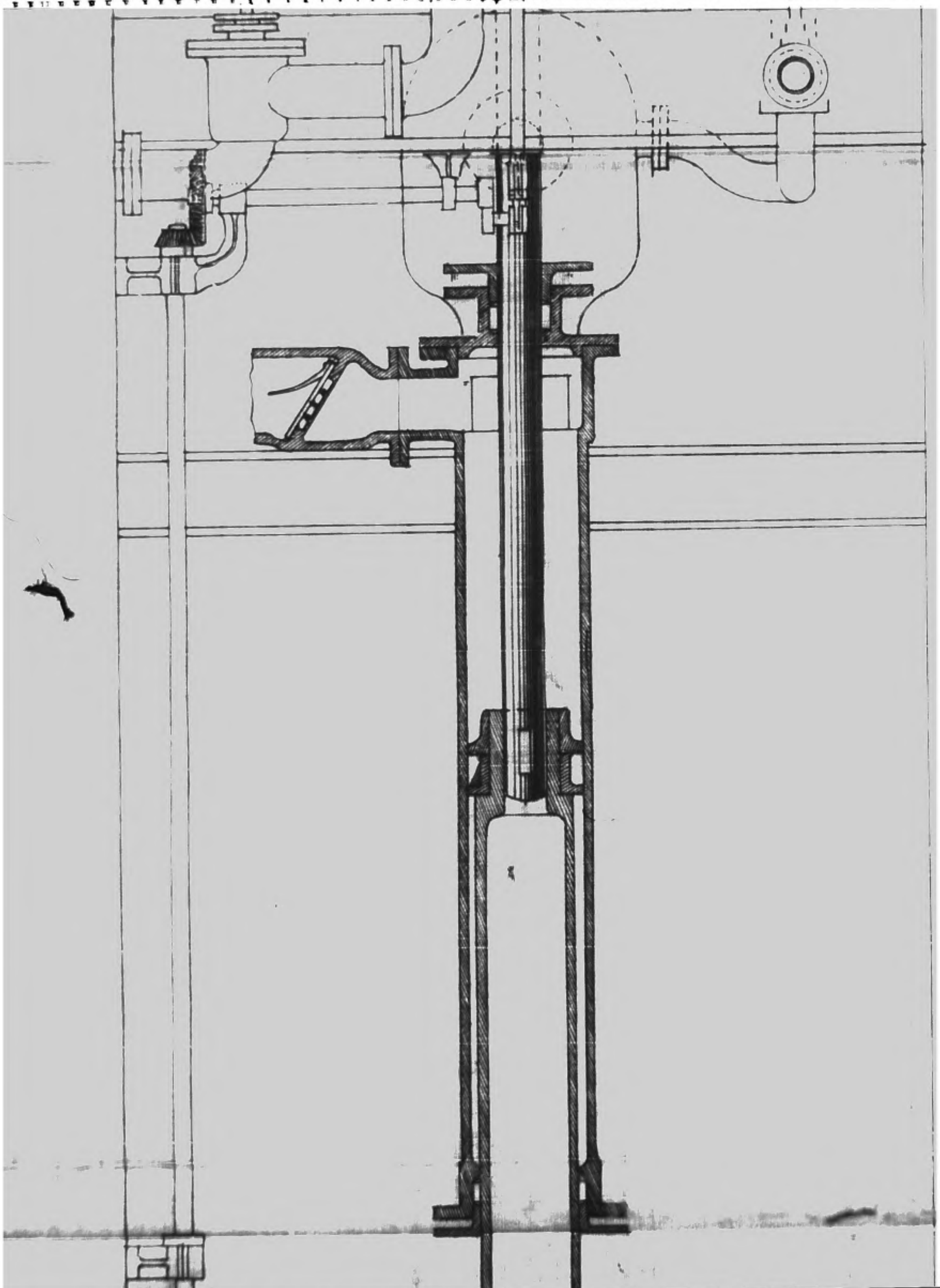


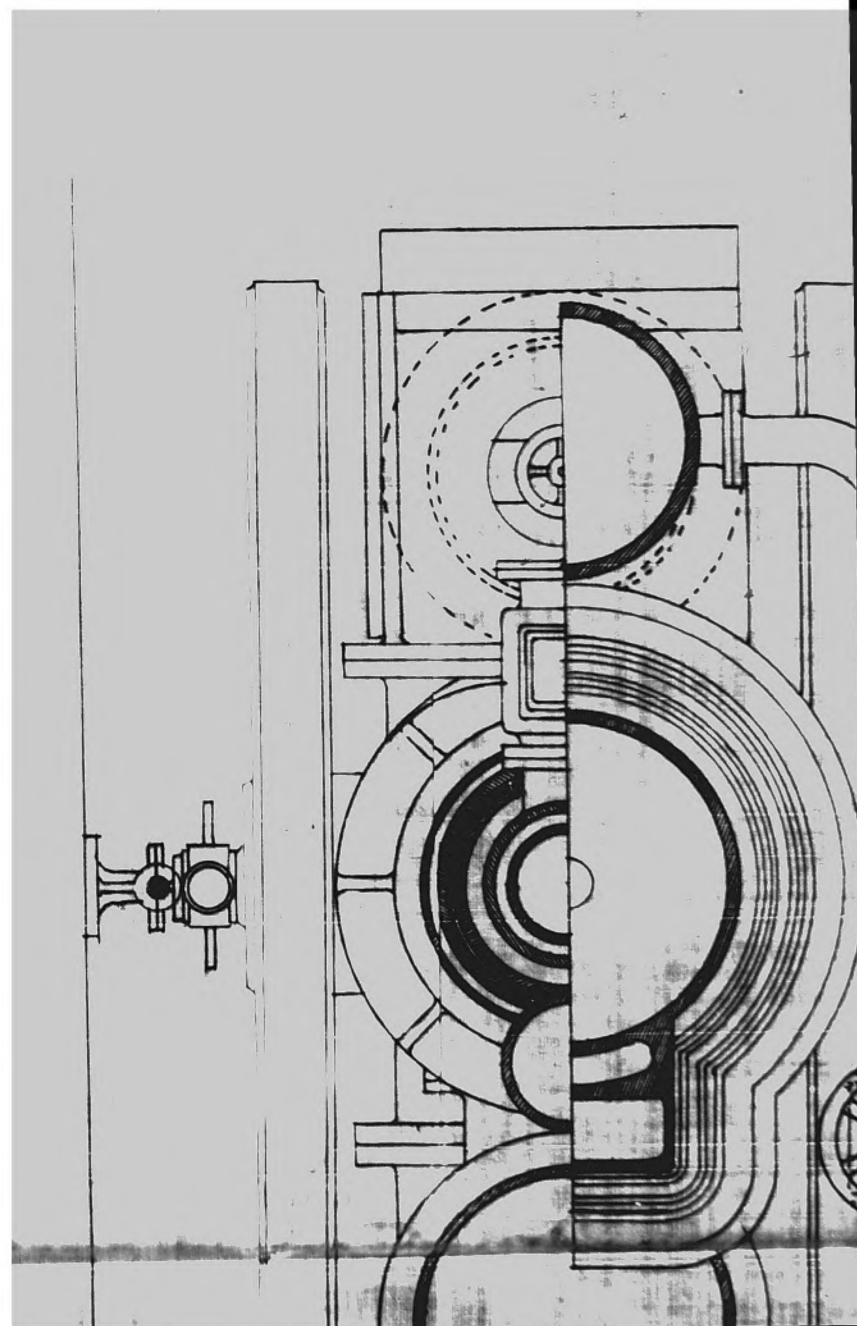
GATE HOUSES

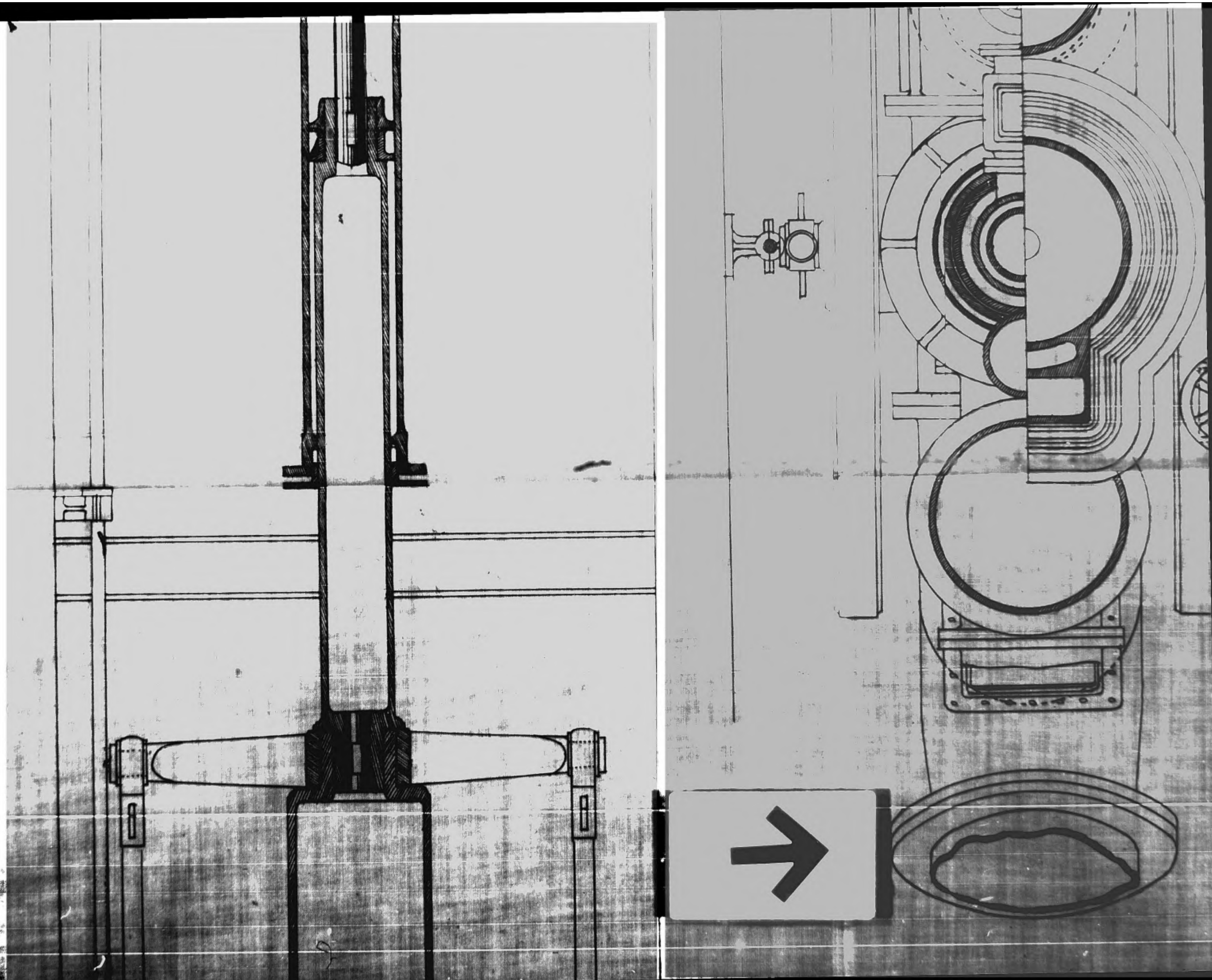
SCALE: 8 FEET-1 INCH



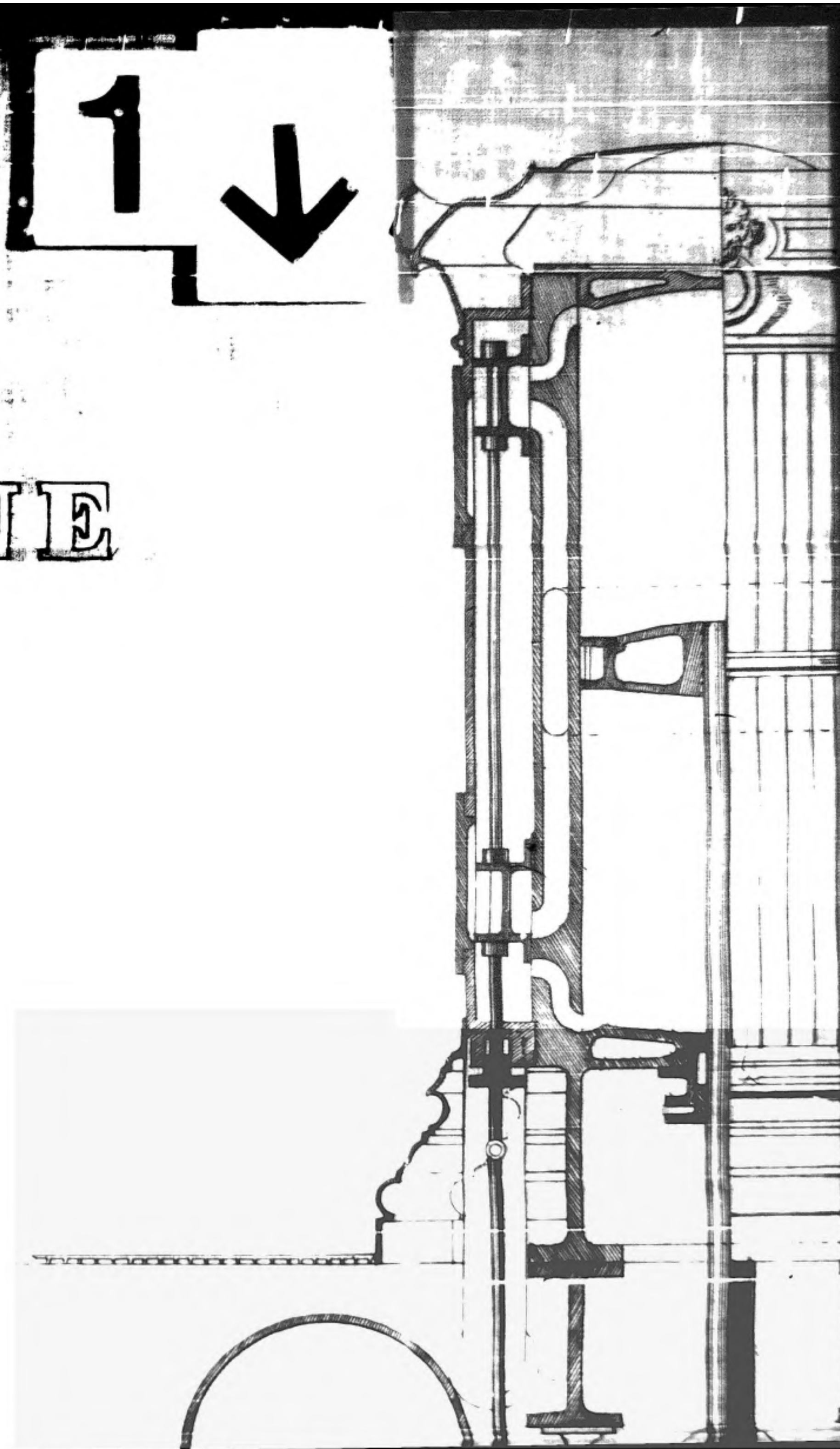
PUMPING E

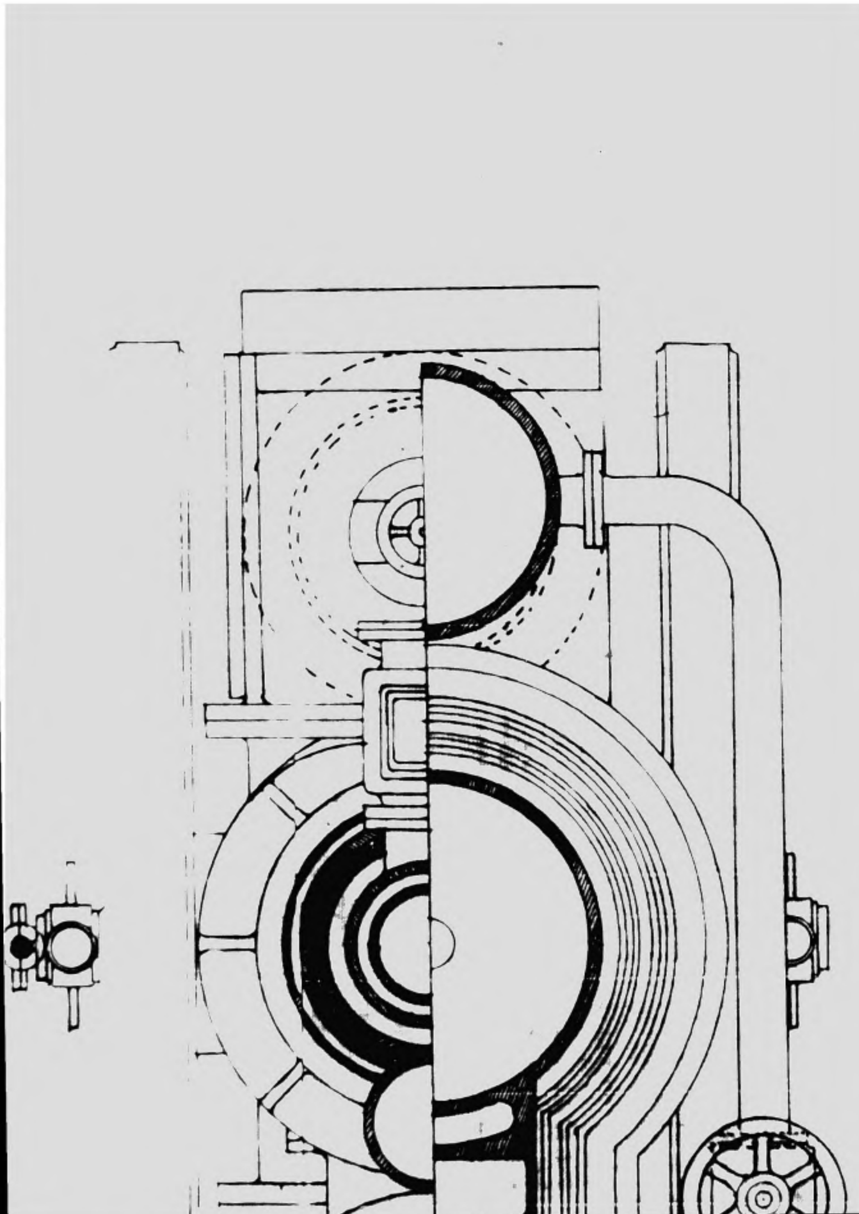
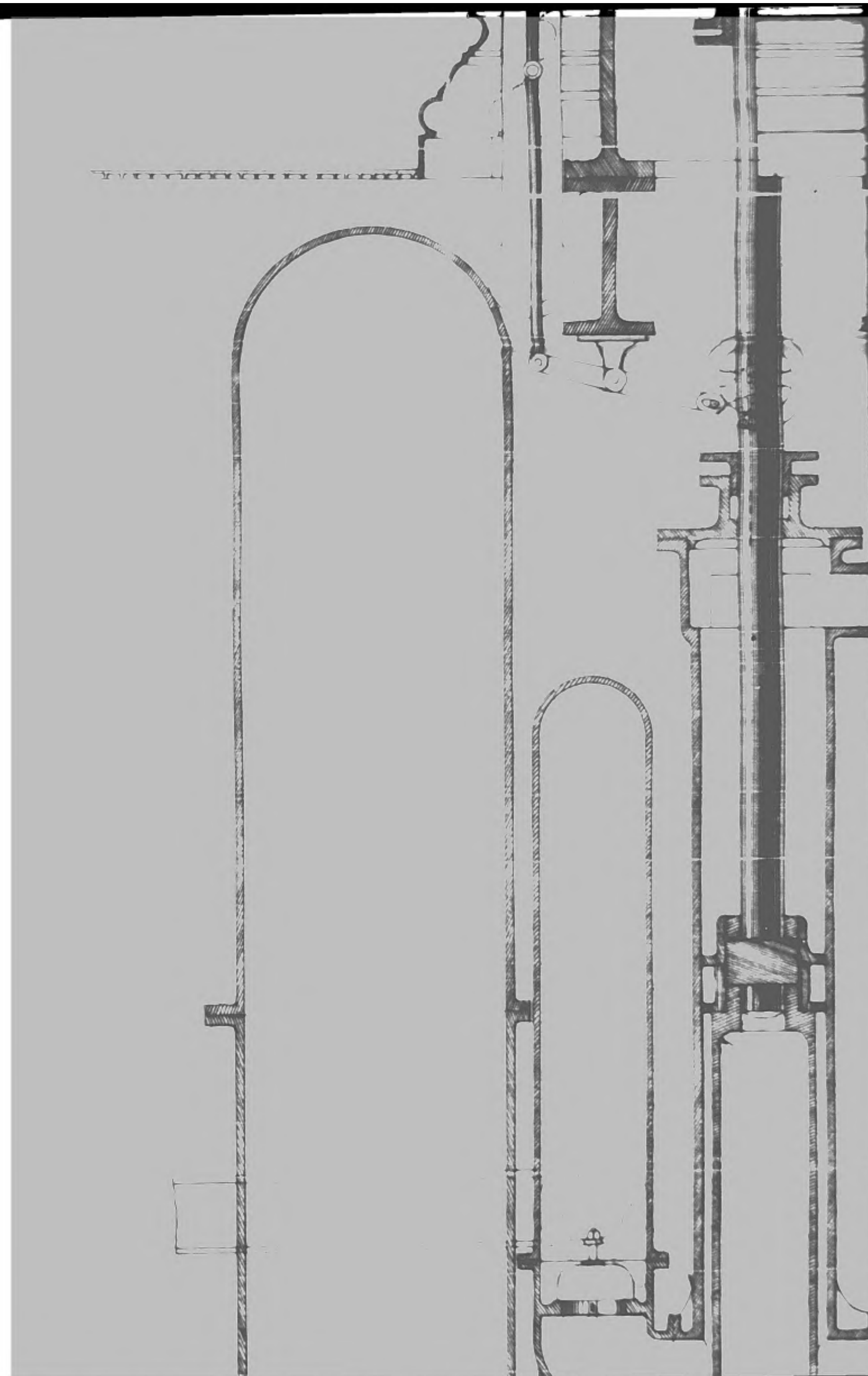


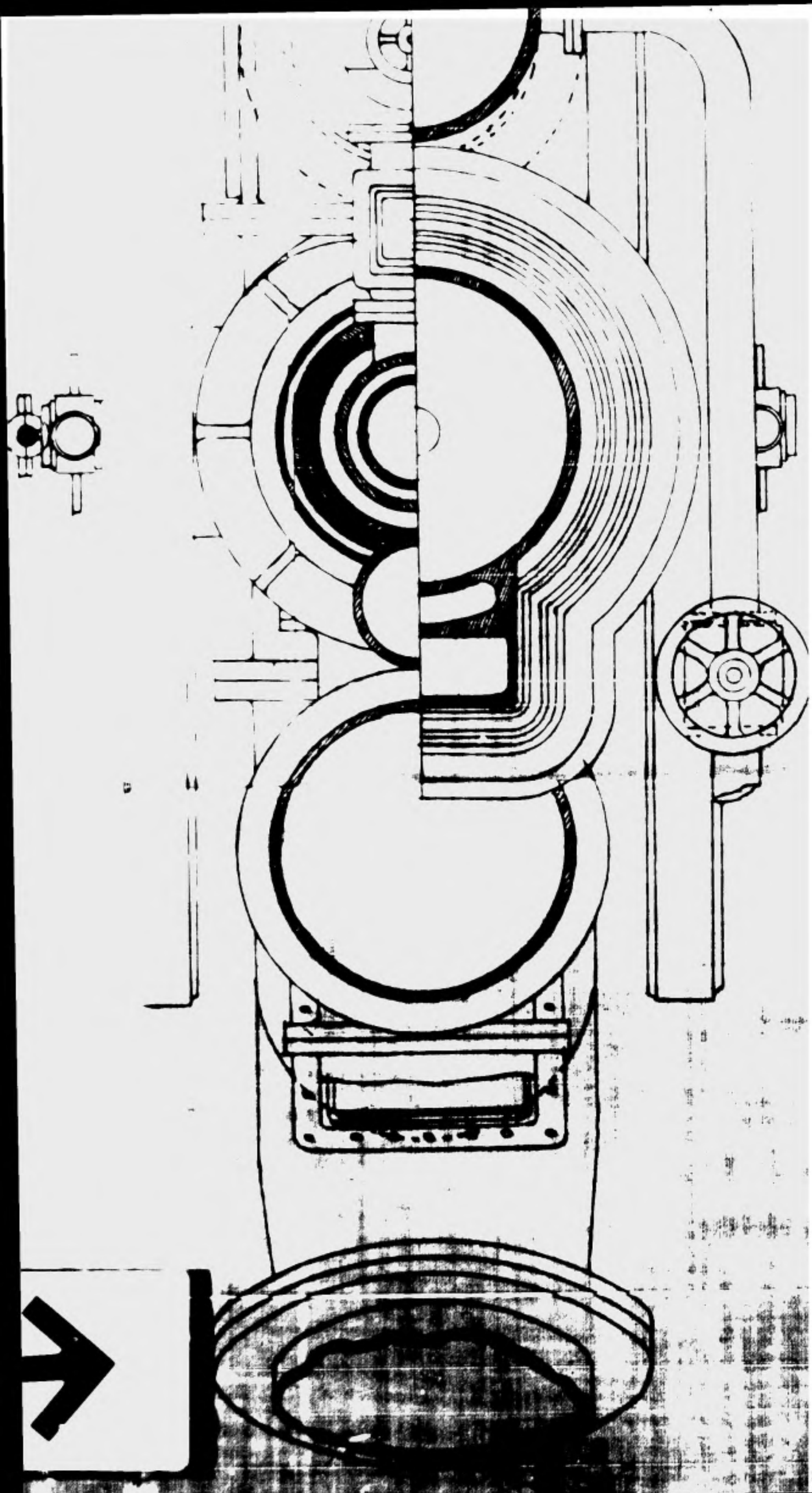


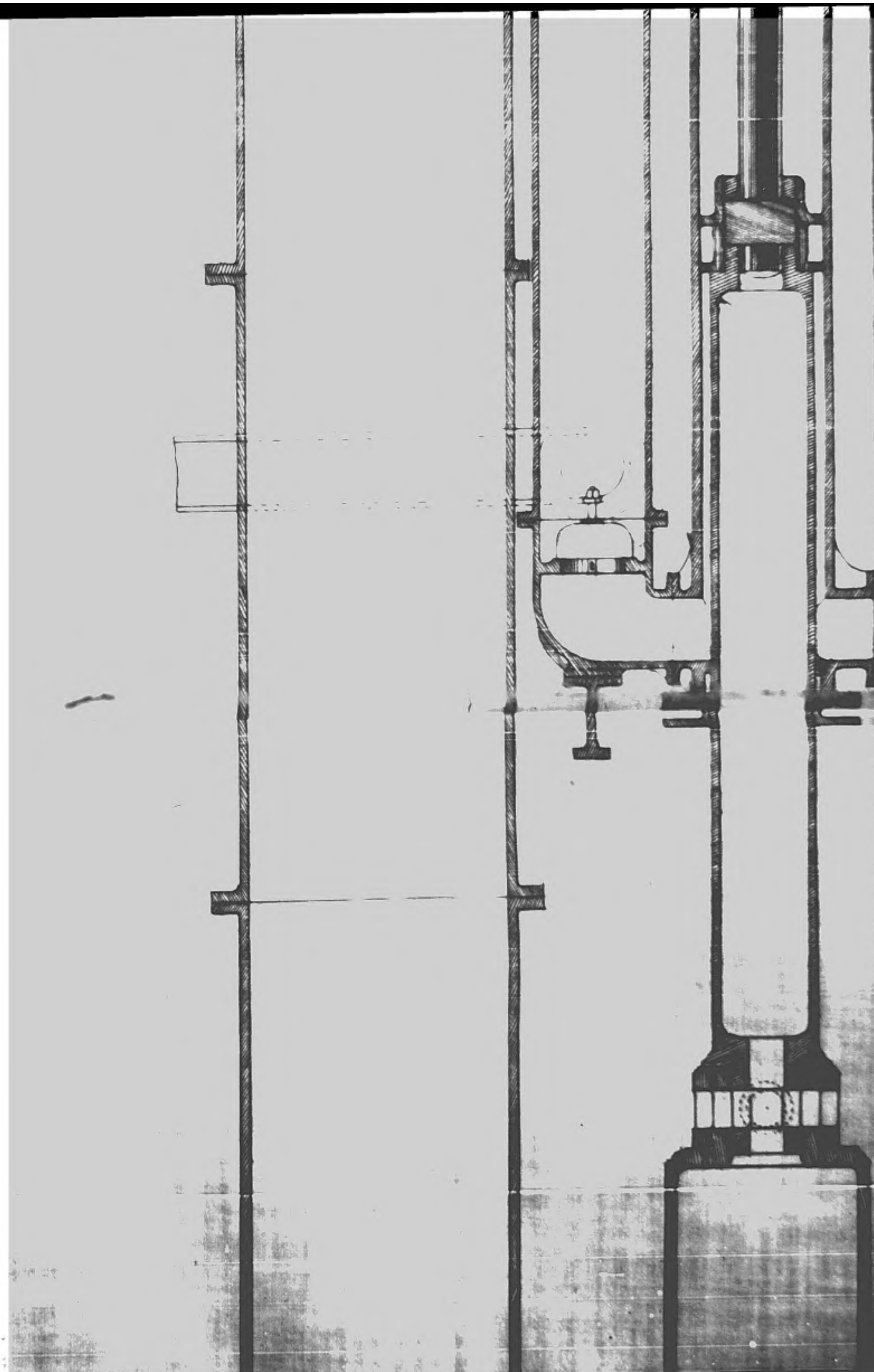


UMPING ENGINE







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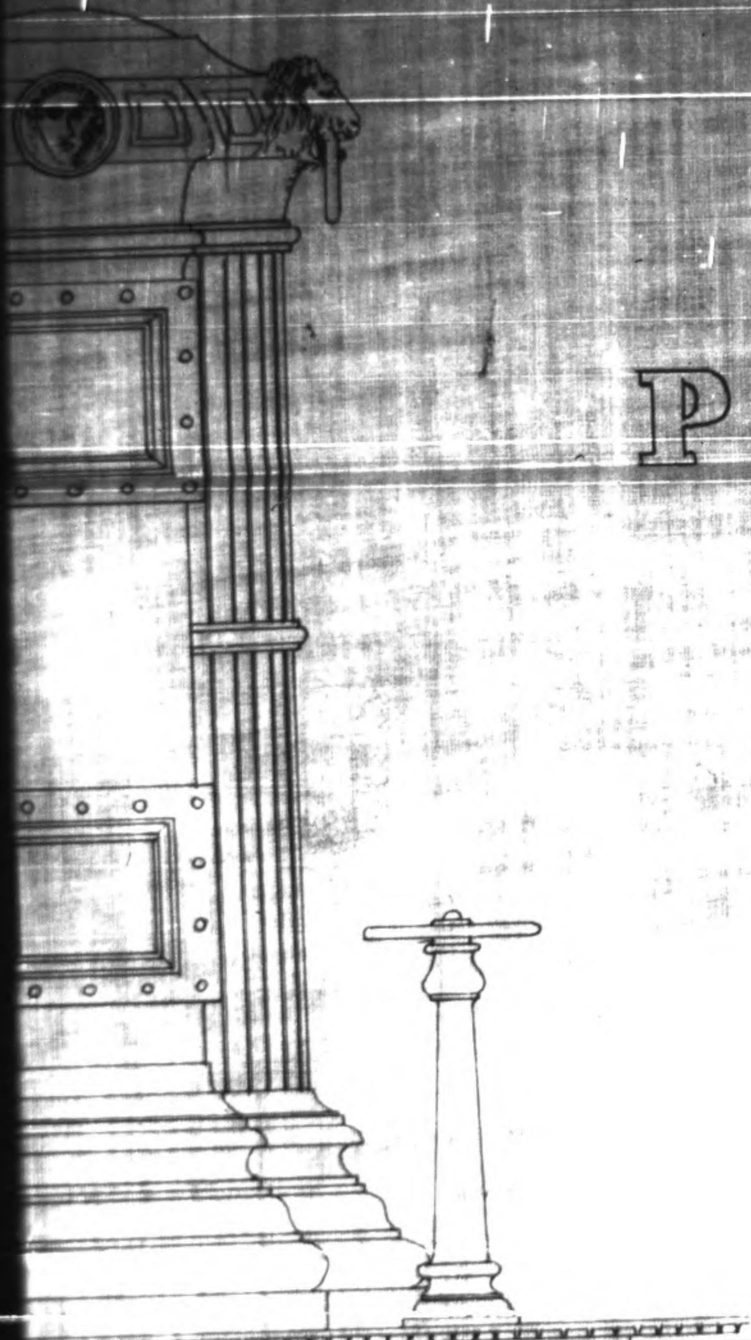

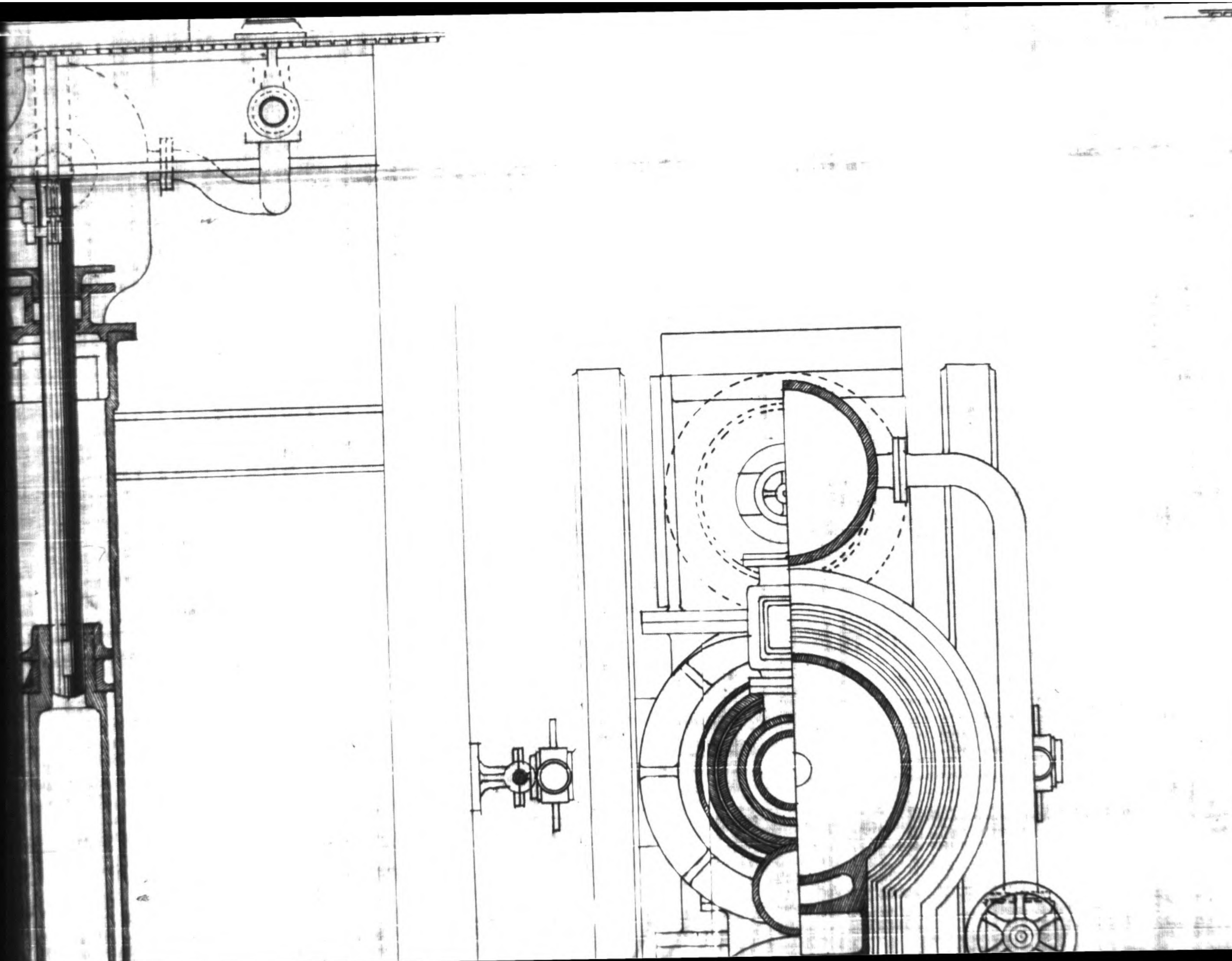

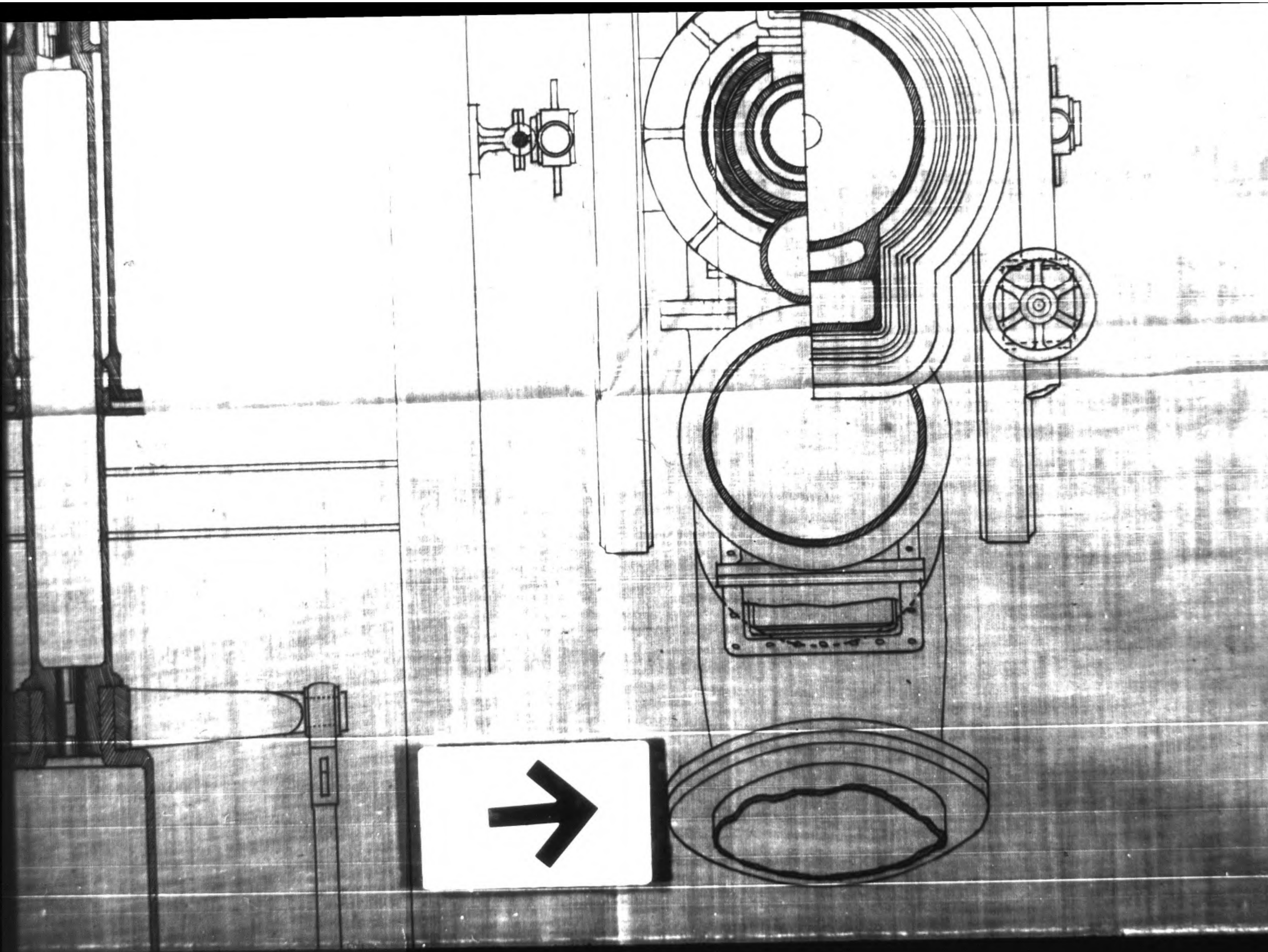

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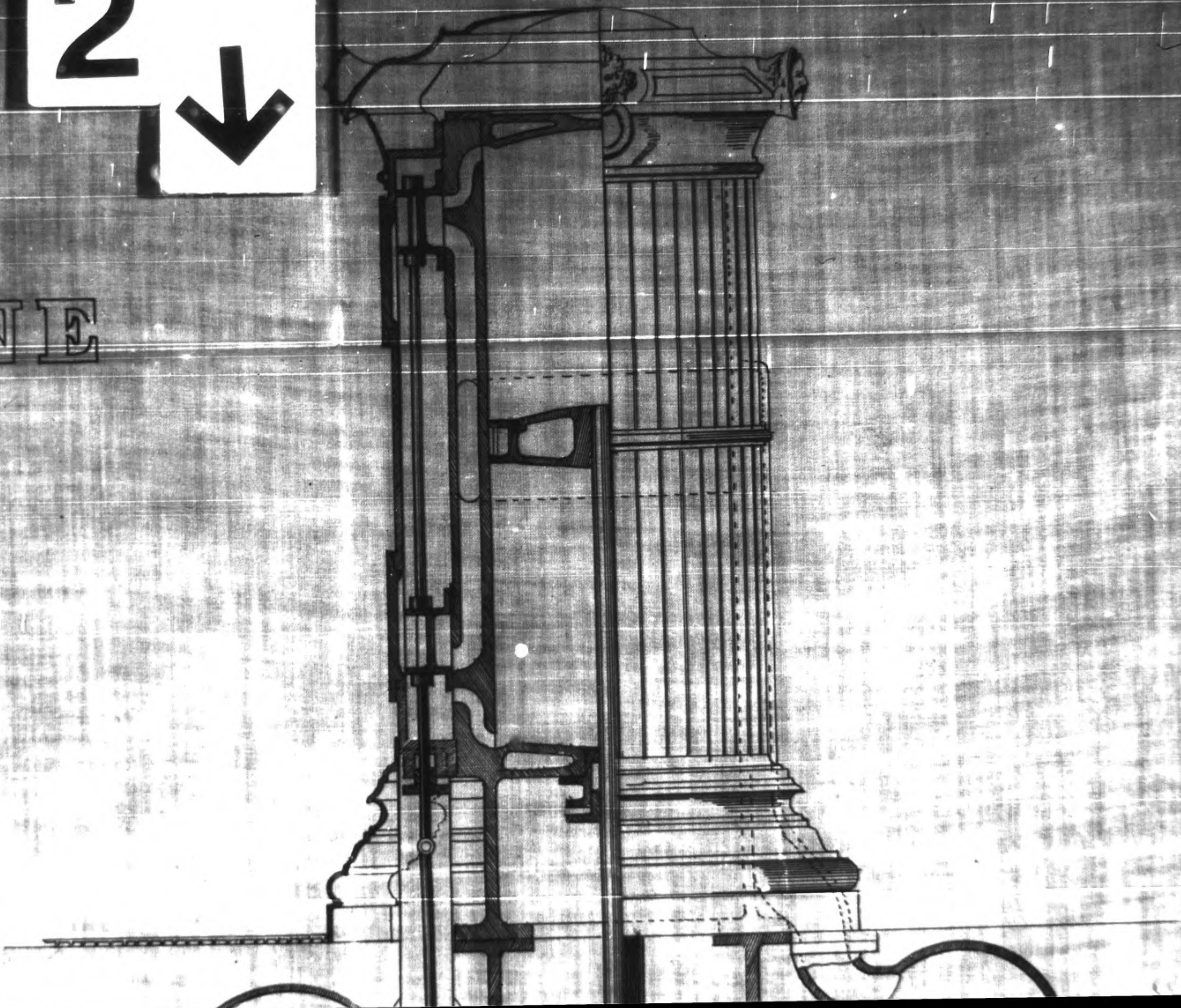
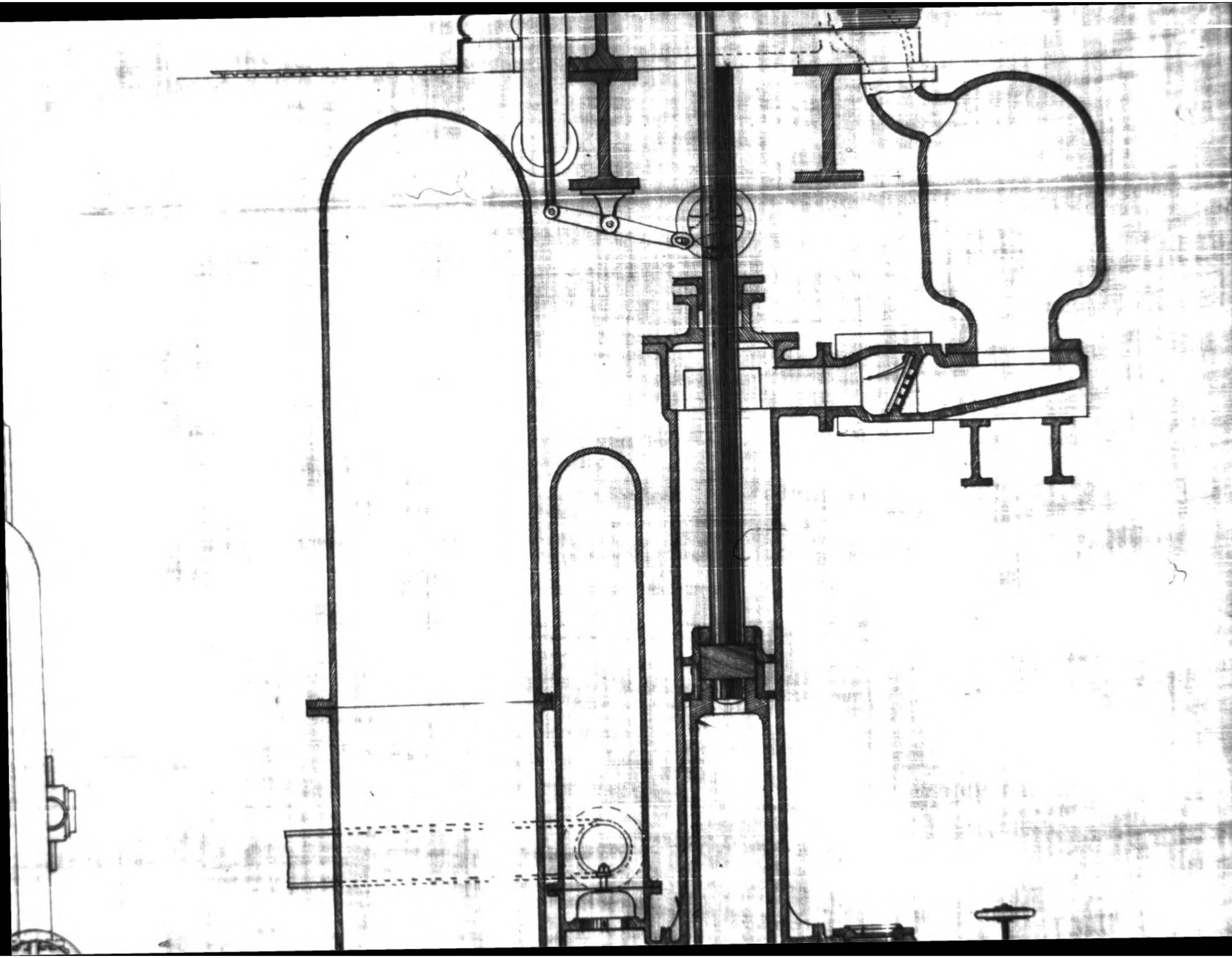
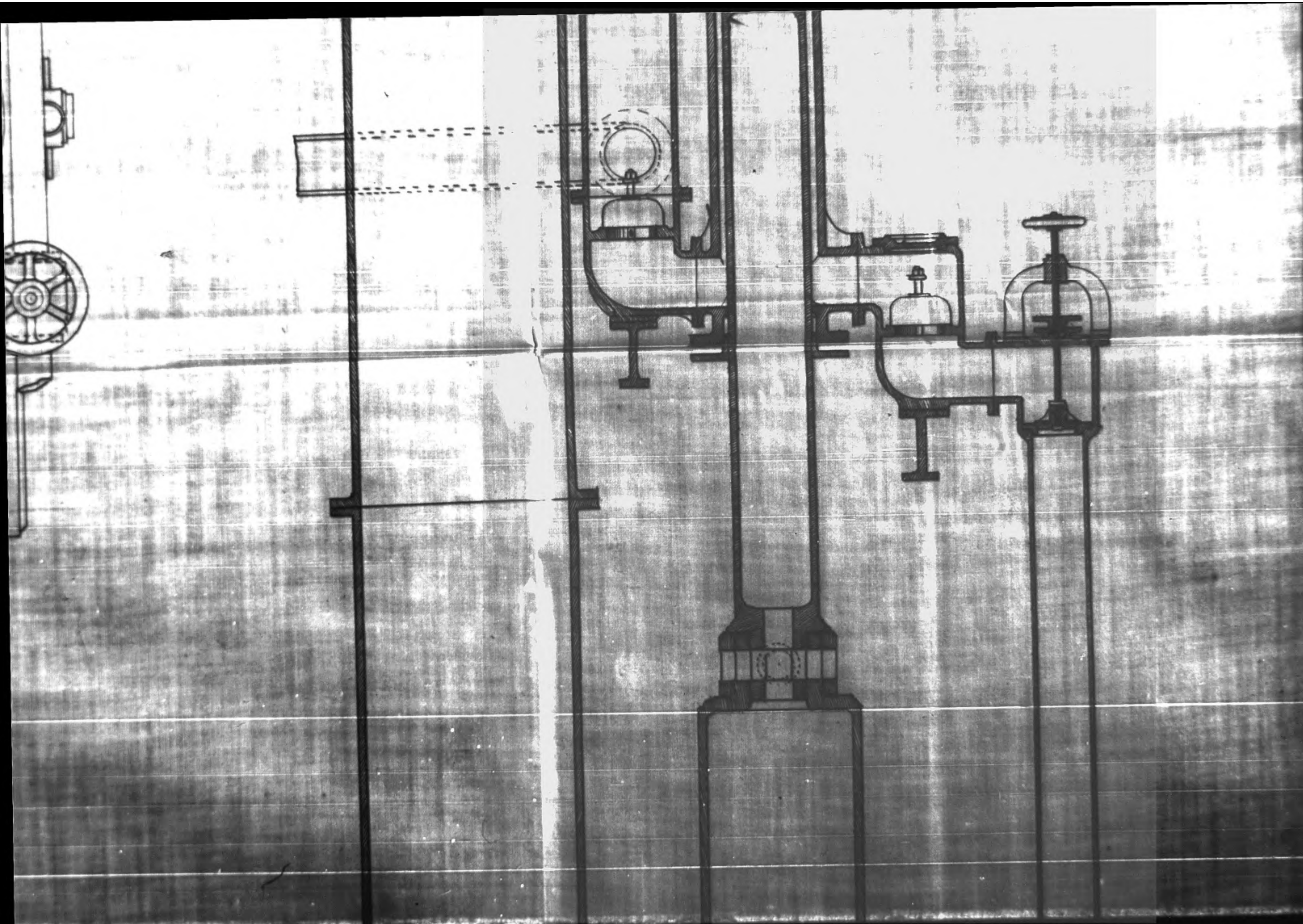
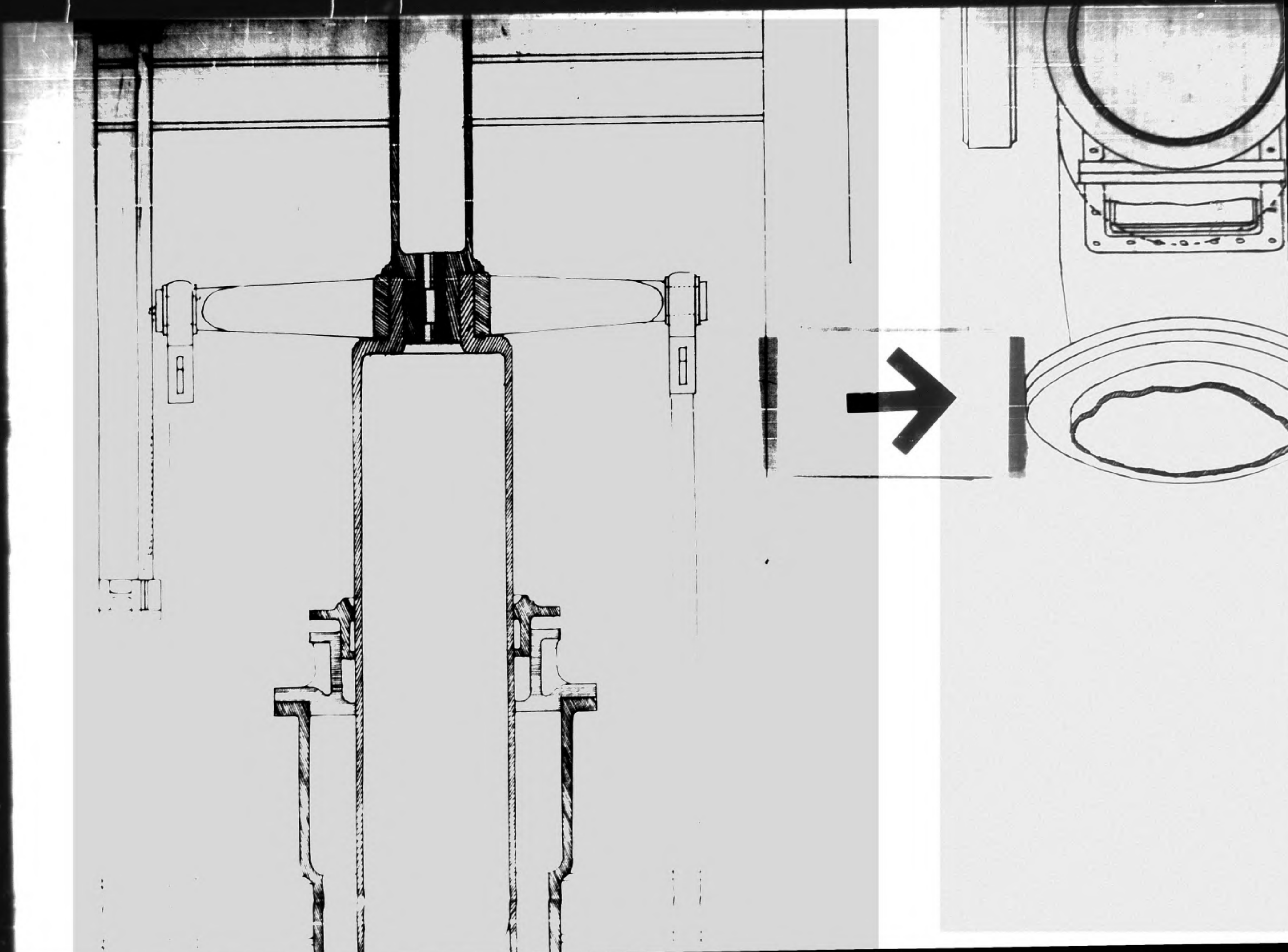
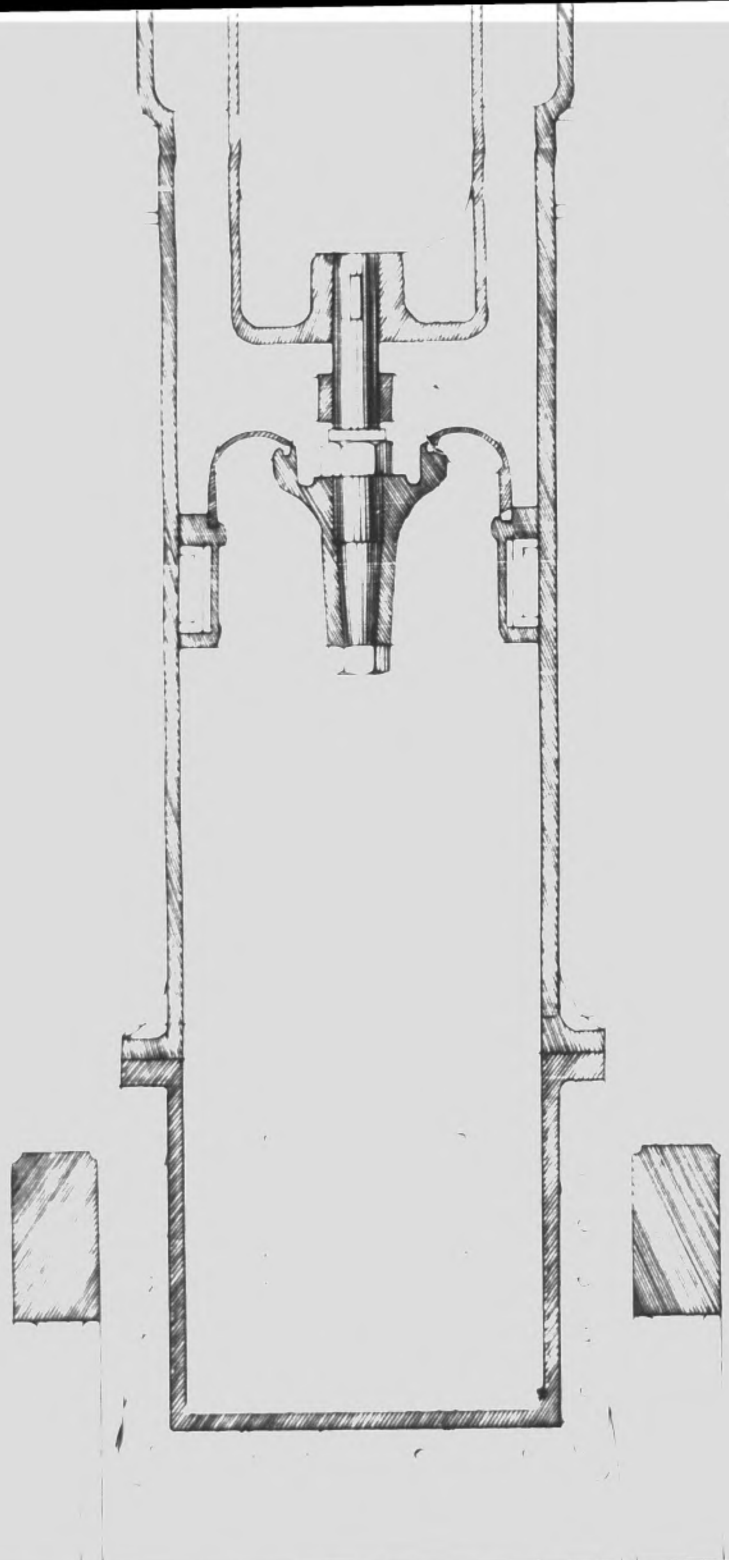
NGINE

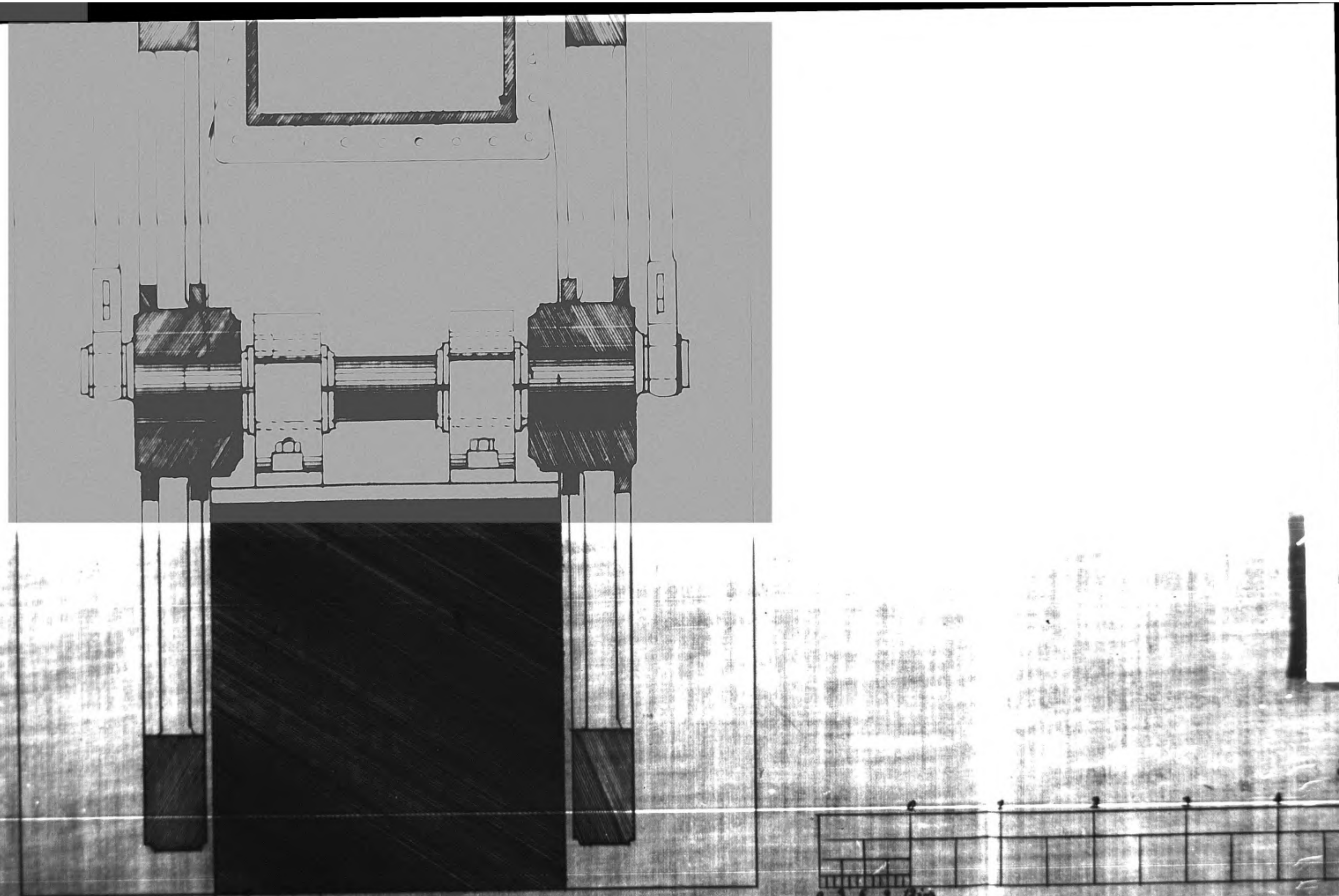








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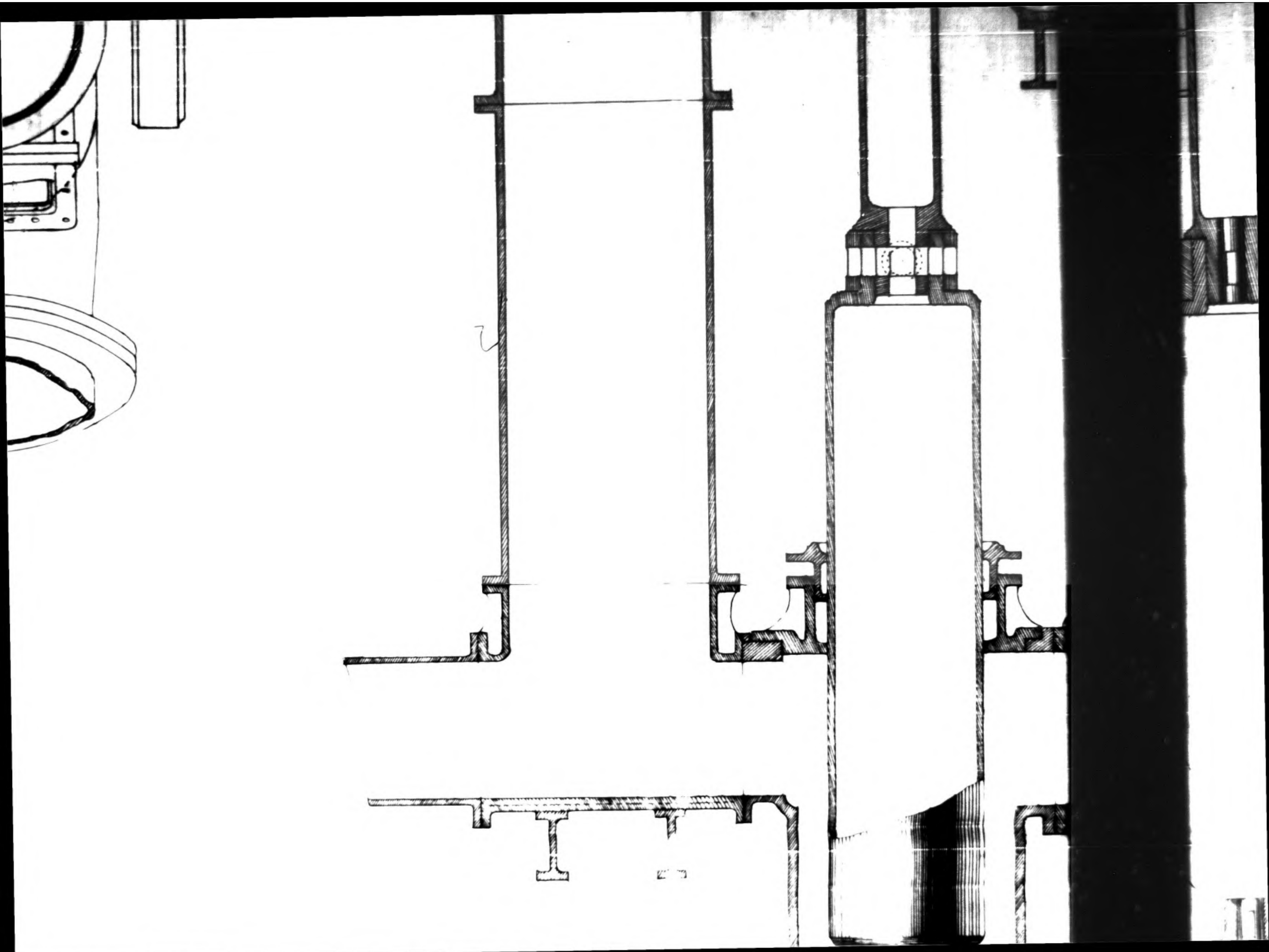

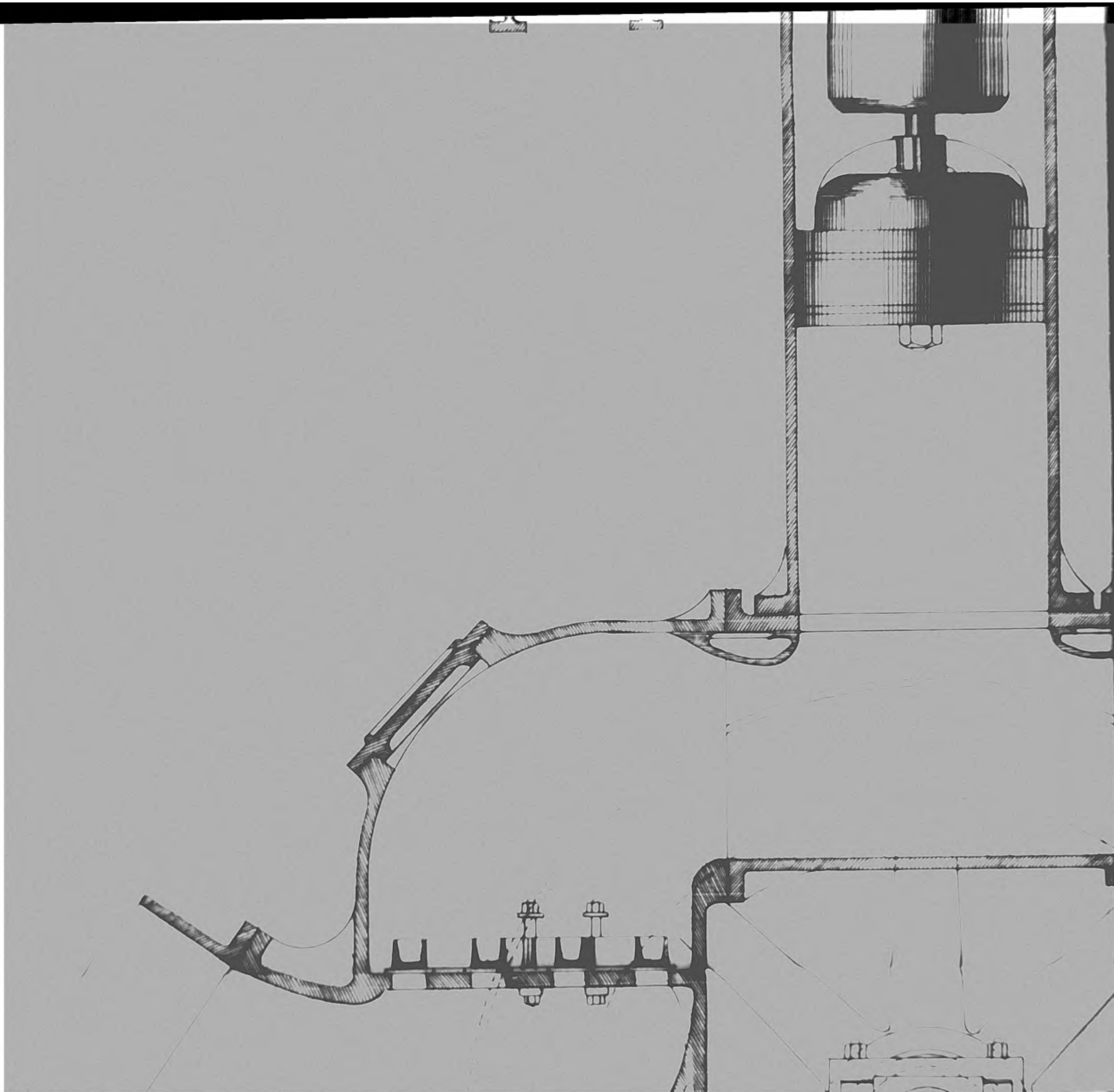

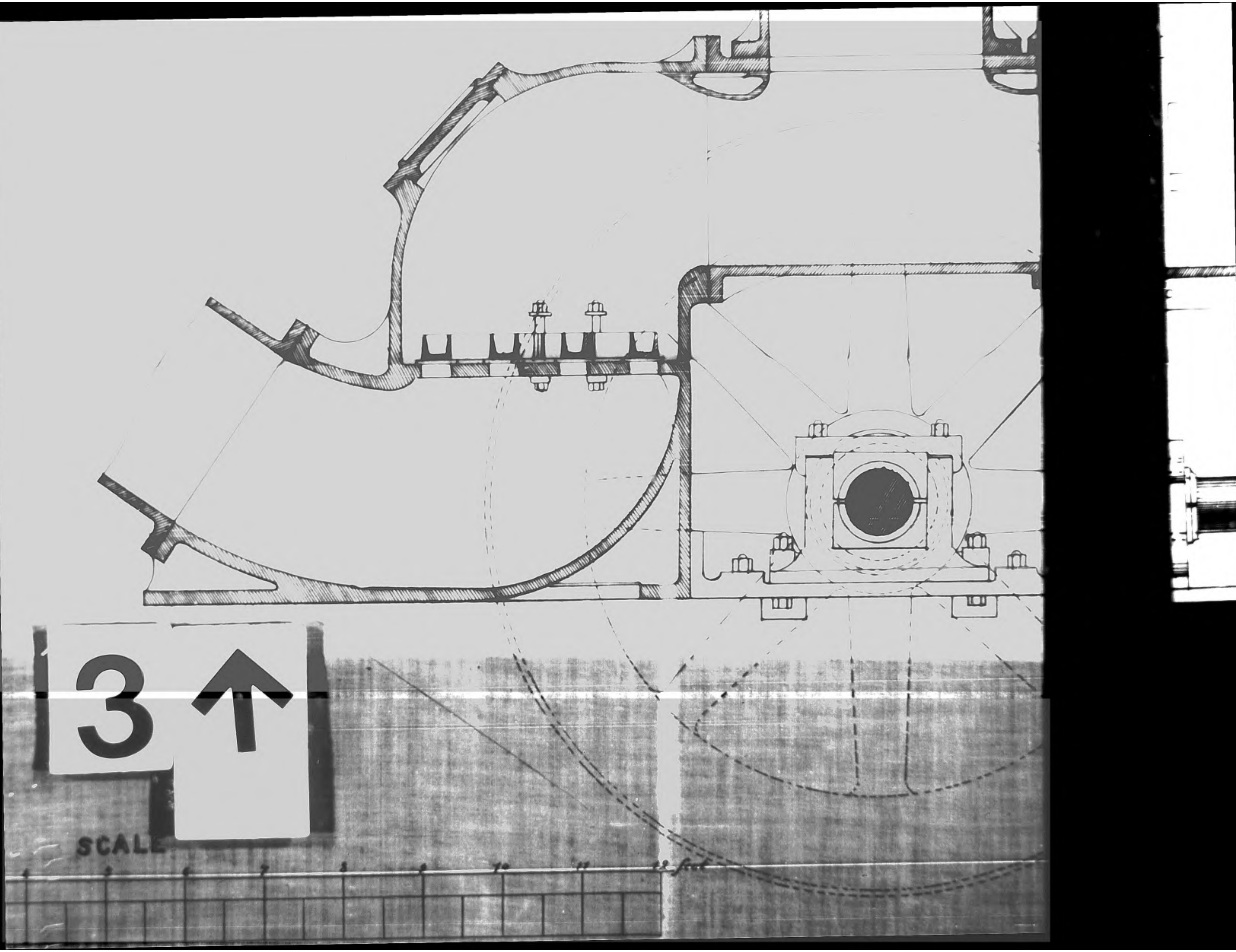
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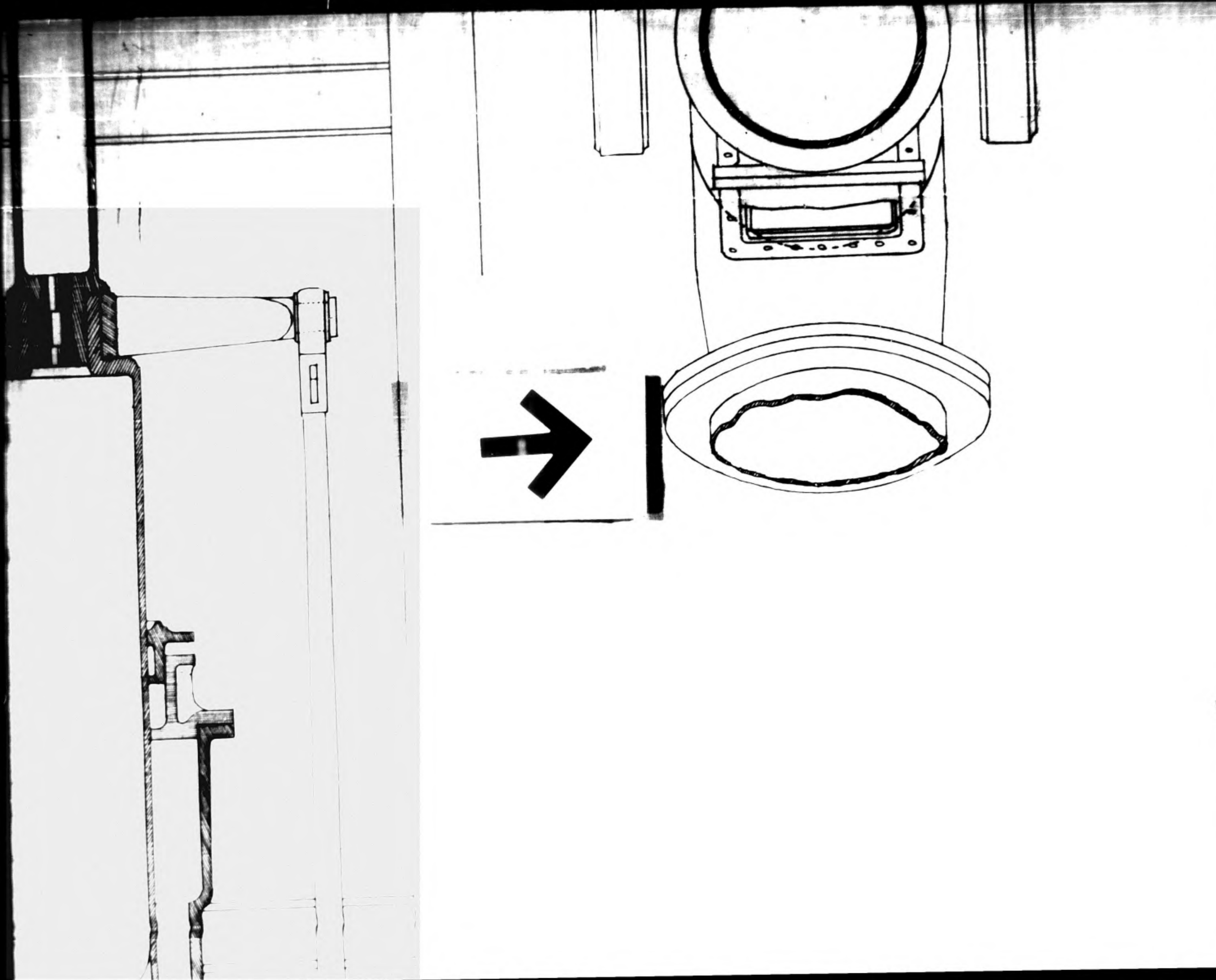

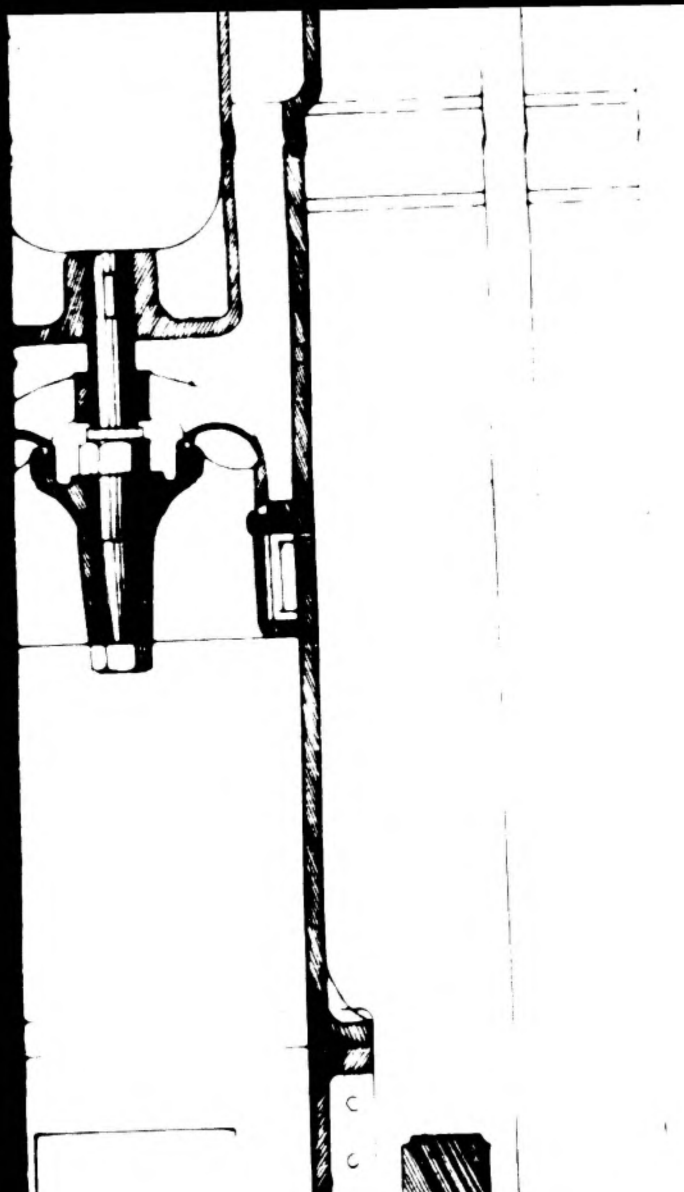

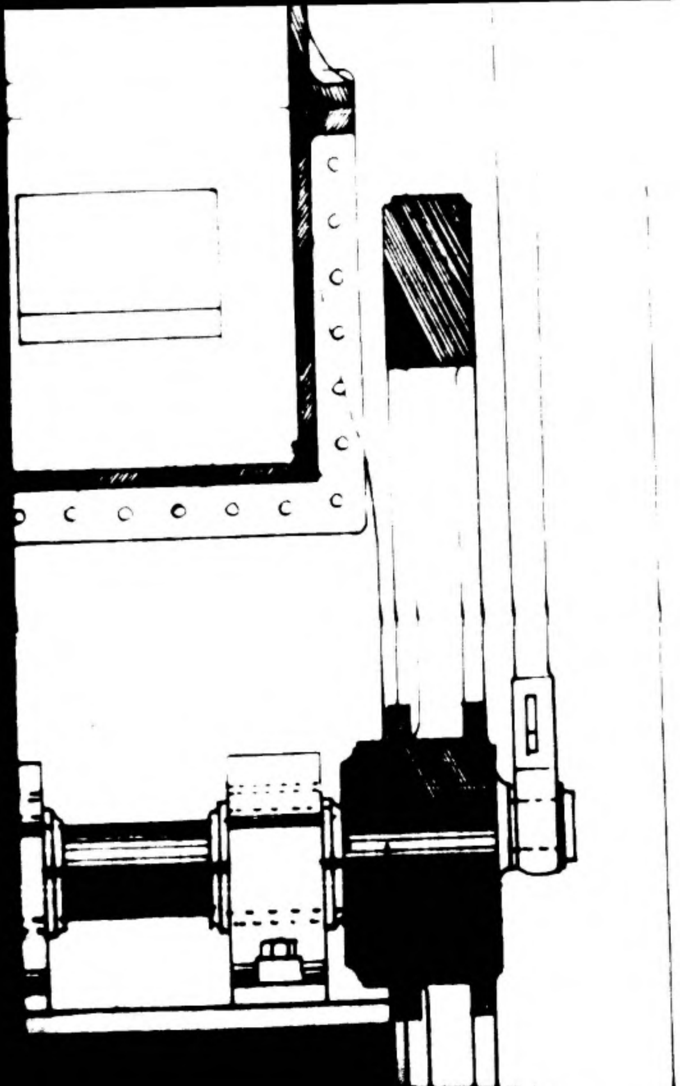

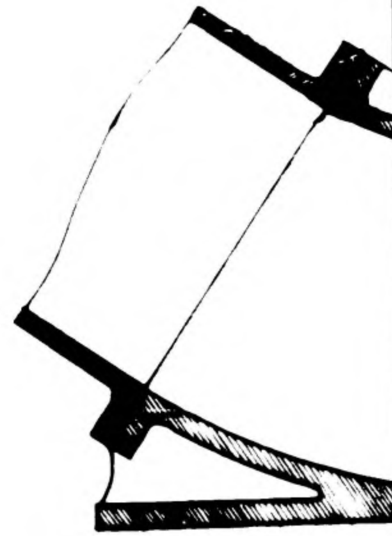

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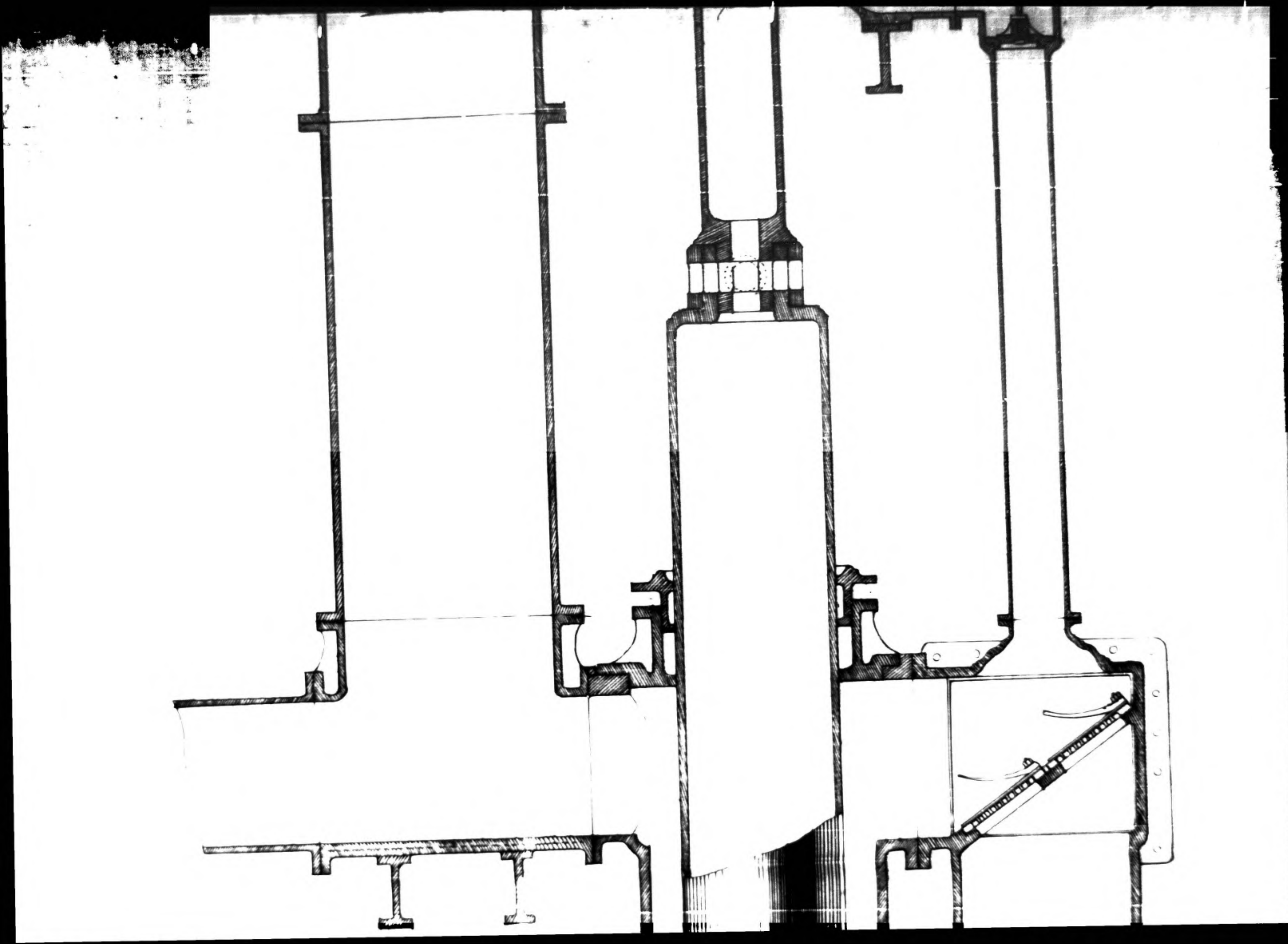

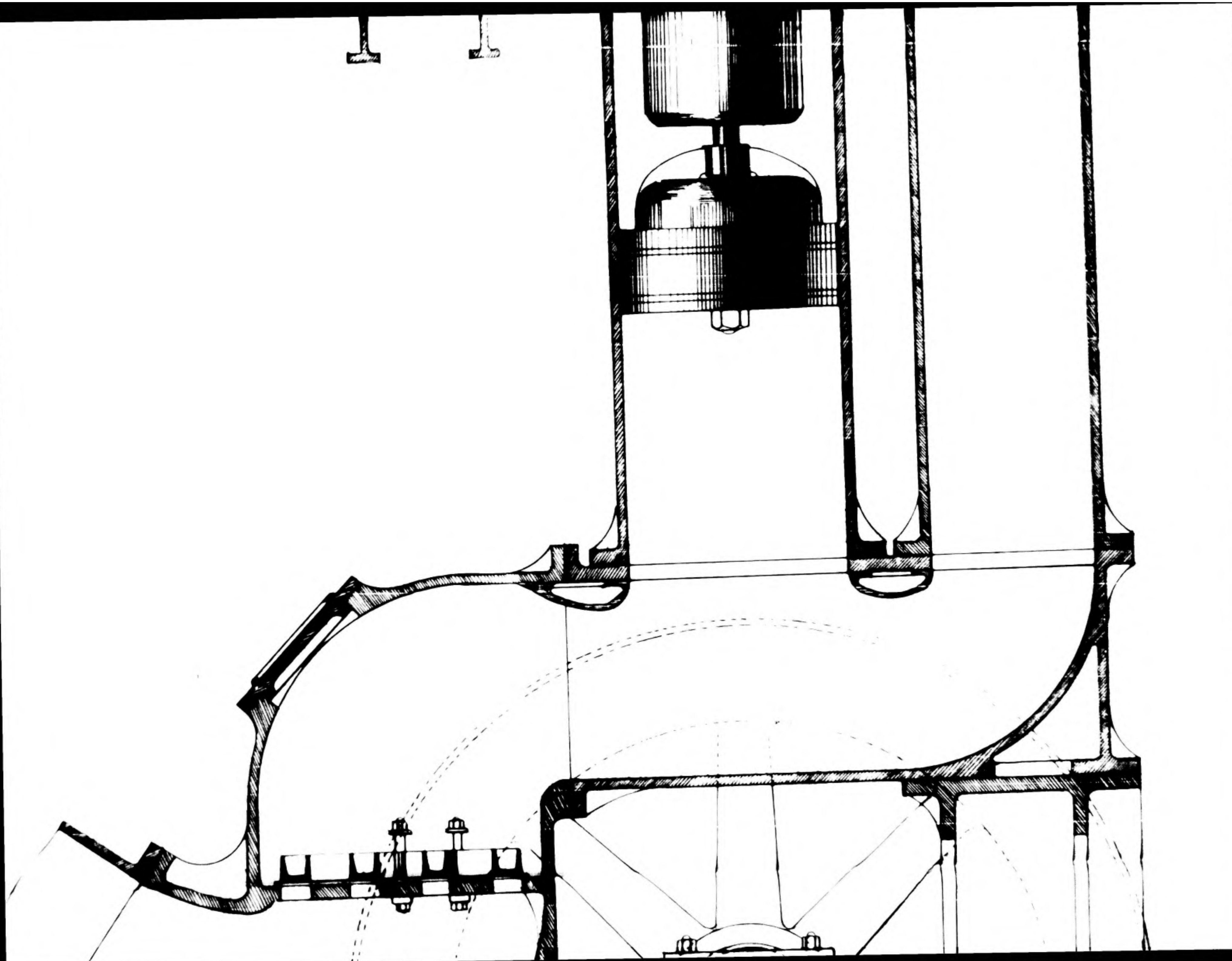

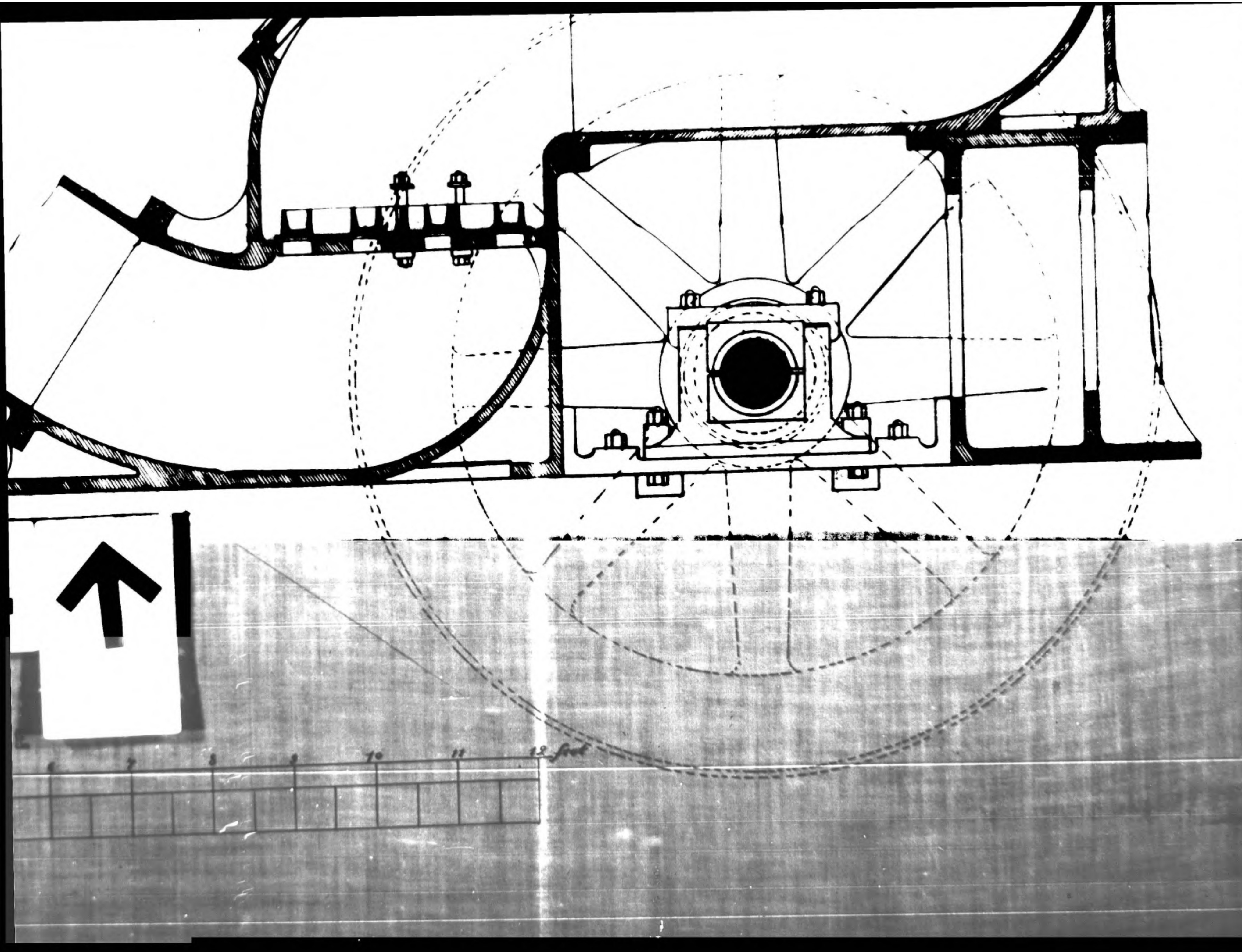
7
8
9
10
11
12 feet