AUTOMATIC RADIAL GATE WATER MEASURING DEVICE

By

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Introduction

Attention was given to the matter of measuring the amount of diversion from the Arkansas River at Pueblo, Colorado, as a municipal water supply for the South Side Water Works or Public Water Works, District No. 2. The problem of measuring the flow had been one of long standing, perhaps over the past 70 years, that the water company has been using water from the river under a decreed appropriation where the measurement of the rate of flow was unsatisfactory. The channel leading from the diversion dam in the river is of concrete, five feet wide, eight foot vertical walls and of flat grade. The water is delivered into the first or primary settling basin which is one of several that constitutes the storage that supplies the pumps which delivers the treated water into the city mains. The problem was complicated because of the variation of stage in the reservoirs, changing stage of the flow in the river and the filling and scouring of the sand and mud deposit in the supply channel. One of the essential criterions being a minimum loss of head in measuring the flow.

Several practical measuring devices were considered as means of solving the problem. The variation in flow from the river may range from about 10 second-feet as a minimum to a maximum of approximately 50 second-feet. The variation of the stage of the settling basin is about 2 feet. The venturi meter, types of weirs, orifices, the measuring flume and other schemes of measurement were investigated but because of the imposed limitations and variation of flow conditions it was finally decided that a radial gate of substantial radius would best suit the situation.

The following pages describe the theory, design and building of the apparatus, installation, calibration and operation of the equipment.

Theory

The principle of measurement is based on an adjustable orifice where a constant difference in head of 0.10 foot is maintained automatically by means of a float control. Since $Q = AV$ then $Q = CA\sqrt{2gH} = CA\ 8.02\sqrt{0.10} = CA\ 8.02 \times 0.316 = 2.53CA$. For design purposes the coefficient of discharge, C, was taken to be 0.65 giving the law of discharge to be $Q = 1.65A$. This relation shows the flow to be directly proportional to the gate opening. For the gate at 1 foot, channel width 5 feet, the area, A, will be 5 square feet and for a difference in head of 0.10 foot the discharge will be 8.25 second-feet. As was later found by actual field tests the value of the coefficient ranged from a minimum of .745 for a discharge of 8.6 second feet to a maximum of .881 at 42 second-foot.

This variation of the coefficient was adjusted through the design of the proper recording chart as will be discussed later.

Design and Building of the Apparatus

A preliminary design was prepared for a light weight radial gate to operate in a channel 5 feet wide with vertical side walls. This design was submitted to the Thompson Pipe & Steel Co. of Denver, for detail plans and construction. The gate has a radius of 7 feet, curved sheet face and light weight angle iron radius bars and bracing and is of substantial construction. The total weight is about 275 lbs. To prevent floating debris from wedging between edges of gate and face of walls a thin pliable rubber sheet, 1/8 inch thick, was attached to the gate to form a seal. Since the pressure head is only 0.10 foot the resistance to movement of the gate is negligable. The gate is mounted on a 1½-inch steel shaft, ball bearing self aligning pillow blocks attached to walls serve as supports. The gate is raised or lowered by means of two high tensile strength 3/16-inch galvanized steel cables wound on grooved drums turned by an electric motor. The lower ends of cables are attached to the bottom edge of the gate about 10 inches in from the face of the channel walls. The gate clearance is about ¼ inch at each side.

Two float wells are located adjacent to the channel where the Ha well has an 1½-inch inlet pipe reaching to a point up stream from the radial gate and the Hb well with a similar inlet to a point downstream from the gate. The two floats are one gallon pottery whiskey jugs so selected to prevent corrosion of copper or brass floats. Suitably mounted on the top of a cabinet covering the two wells is the electrical float control that govern the movement of the radial gate. This instrument consists of two 3/8-inch brass tubes that serve as shafts, ball bearing mounted, and each carries a sprocket wheel that engages the brass ladder chain attached to the float. Suitable counter weights balance the position of rotation. At the inner ends of the two shafts is provided the electrical contact mechanism. Attached to the Hb shaft is a 5-inch mahogany disk having a 1-inch face and at the end of the Ha shaft is an arm that carries two silver contact points spaced 0.095 foot apart. When in neutral position these two contact points are 0.005 foot removed from the stainless steel ends of the insulated strips mounted on the face of the 5-inch disk which are 0.10 foot apart. The two silver contacts move over a piece of glass curved to the radius of the disk. From the contact arm is an insulated No. 22 copper wire, A, threaded through the Ha hollow shaft to the outer end and wires B and C are threaded through the Hb shaft and attached to the two independent stainless steel strips on the disk. When the difference in head between the water surfaces upstream and downstream from the gate is 0.10 foot, the respective floats turn the system to a neutral position for that particular rate of discharge. On each sprocket shaft is mounded a 5-inch disk, 1-inch face, that carries a brass ribbon, enameled white, and graduated in black in feet, tenths and hundredths of foot. A fixed index point is mounted on a post along side the disk. These scales indicate the depths of water above the sill of the gate on each side of the gate. When in neutral position the readings differ by 0.10 foot. The base of the instrument is of mahogany about 3/4-inch in thickness and 7x30 inches in plan. A sponge rubber seal is provided around the base upon which rests the cover that has a pane of glass at the top to permit full view of the instrument. The float control electrical circuit is 24 volts, AC, provided by a transformer located in the main control panel.

The source of power for this installation is a 220 volt, 3 phase circuit into the control panel as shown in the accompanying wiring diagram. Figure 7 shows the control panel with door of case open. The timer is the instrument at the right side, GE type with glass seal cover. The float control circuits terminate in this timer which contacts every 10 minutes for a duration period of 16 seconds. Should the Ha float be 0.01 foot high or the Hb 0.01 foot low the silver contact will be on the appropriate stainless steel strip to complete the circuit. Should the Ha contact occur, say 4 minutes after the timer passed the zero time, and remains in this position to the end of the 10 minute period, the circuit is then completed to cause the ½ HP motor to rotate for 16 seconds to lift the gate through a series of speed reducers by about 0.04 foot. Since the difference in head at the time of contact was 0.11 foot this increase in the gate opening will tend to lower the upper head. If this change is sufficient in amount the Ha float will drop and open the contact to neutral position. If this adjustment is not enough and the float contact is still touching the stainless steel strip then when the timer again completes the 10 minute interval the gate will be raised another increment of opening. Should these two upward movements of the gate prove to be too much then the difference in head may settle down to 0.09 foot and the opposite float contact will be completed to cause the motor to rotate in the opposite direction and the gate will be lowered. When the apparatus is under automatic control a change of the rate of flow from the river may occur or the water surface in the primary settling basin may change due to the pumping demand for city distribution or possibly increasing Hb head caused by more water entering the basin than is withdrawn. These changing conditions are automatically adjusted as required by the float controls. Figure 8 shows the control panel with the door of the case closed. Here at the center is a handle pointing downward to signify the apparatus is in automatic operation. If in the event it is required to diminish the flow from the river by, say as much as 5 second-feet, the operator will close the head gate to the extent he estimates to be necessary to reduce the flow by 5 second-foot. He then moves the handle on the panel case to the left or manual operation and in doing so the timer is cut out of circuit and the motor will operate to lower the gate to the required opening for the reduced flow. To be described later is an indicating disk which points out the actual flow before the change of the head gate occurred, assume this to be 30 second-foot. The manual operation of the motor rotates this disk until the indication is 25 second-foot. The operator then turns the handle to automatic and finally the float control will adjust the gate to the proper position which may be more or less than the discharge sought because the operator only estimated the amount shut out by the head gate adjustment. The manual operation is a matter of convenience. The automatic control would in a course of several adjustments at 10 minute intervals catch up with the change in discharge whereas when manually operated the approximate gate setting can be accomplished in a matter of a few minutes. Should it be required to admit more water from the river than for manual operation the handle on the door is turned to the right.

The motor that operates the radial gate can be reversed in rotation by relay contacts in the control panel. The motor is geared down by a series of reduction gears to the 1¼-inch steel shaft that carries the cable drums. The weight of the gate is sufficient to keep the cables under tension at all positions thus the gate movement is very positive.

Four long 5/8-inch threaded bolts anchored in the frame of the motor assembly supports a platform over the mechanism upon which is placed the recording instrument. The chart cylinder is turned by means of a ¼-inch round leather belt driven by a grooved pulley on the drum shaft. Any movement of the gate causes the chart cylinder to rotate through a series of small gears to such positions of discharge as indicated by the gate opening. The penblock is moved to the right by a horizontal threaded 3/8-inch steel rod where the block has two split nuts, 26 threads per inch, that rides on the top of the threaded rod. A small 220-volt telechron, ratio 1 to 10, is geared to this rod at one end. The rod is provided with ball bearings. The chart is designed to cover 8 full days in time horizontally and for discharge ranging from zero to about 50 second-feet vertically. The nominal operation is confined within 10 to 40 second-feet. The chart cylinder is mounted on a brass tube and at the right end is a knurled thumb nut that when tightened locks the cylinder to the gear that is turned by the small leather belt. When the nut is released the chart cylinder may be rotated freely to any position. To change the chart the pen block is lifted off the threaded rod and set aside, the knurled nut is loosened and the cylinder rotated to have the long spring clip that holds the chart at a convenient setting for handling. After the new chart is in place the cylinder is rotated to approximately the correct position and then the pen block is set on the threaded rod at the correct time and then the cylinder turned to show the pen at the correct flow as indicated by the discharge disk. This accomplished , the knurled thumb nut is tightened to start another weekly record. Since the pen block is moved by the telechron the time of travel for the week is probably within an error of a couple of minutes and failure of the operator to remember to wind a clock drive is eliminated. Since the movement of the cylinder and pen drive are positive, the instrument is capable of turning out a perfect weekly record. The record is scribed in red ink. See general drawing for instrument details. Figure 6 Shows the upstream face of the gate. At the right is shown a short piece of 3x3x$\frac{1}{4}$-inch angle bar welded to vertical roof support at one end and to the 7-inch channel that supports the cable drums at the other end. The top edge of the bar is level. The bar is set such as to have the gate clear within about 1/8 inch. The top point of the gate may be either above or below the edge of the bar. This distance is observed by a scale in hundredth of feet as a direct measure of the gate opening and since the rate of discharge is directly proportional to the area under the gate then the scale reading is likewise proportional to the discharge. On the door of the chart cabinet is a plotted curve. The base line on this chart is horizontal midway on the vertical axis and the discharge in second-feet as the abscissa. The plotted calibration curve sweeps upward to the right across the diagram at a liberal scale. The use of this diagram is quite simple. The scale reading, tip of gate above or below the index bar, when applied either above or below the base line of the diagram, shows directly the discharge through the gate. This simple scheme permits checking easily the rate of flow as shown on the indicating disk and then to observe that the instrument record is in agreement. This determination of the flow will be correct when the Ha and Hb depth tapes on the float control instrument differ by 0.10 foot.

The picture of the upstream face of the gate also shows a vertical extended accessory that serves as a trip for the limit switch to prevent the gate from being lowered to complete closure and possible slack in the lifting cables, likewise a limit switch controls the movement of the gate at a safe limit of opening to prevent the possibility of undue tension of the cables. Manual operation of motor permit the gate to be raised well above the water surface to meet ice conditions during the winter months when the gate is not used for flow measurements.

The equipment is housed in a substantial concrete block shelter, gravel-tar roof, concrete floor and metal sash windows of ample size for lighting. Electric light inside and under the canopy over gate for night operation. Premises enclosed with 6-foot cyclone wire fence, and padlocked gate. See Figure 1 and general drawing for details.

Analysis of Calibration Data

The only practical method of calibration available was through the application of current meter gagings, made in the supply channel from the river taken both upstream and downstream from the radial gate installation. The upstream measuring station was at a point where the width of the section was 2.5 feet wide and about 6 feet deep, concrete vertical walls and smooth level floor. The downstream station was in the concrete channel, 5 feet wide, 8 feet deep, firm mud and sand bottom. The 0.6, 0.2 and 0.8 depths of velocity measurements were used as the methods of gaging.

Appended is table 1 showing the experimental data. At the time each gaging was made, careful notes were taken showing the readings of the Ha and Hb depth tapes on the float control instrument, position of gate, time of observation and other pertinent information. The first four observations, A-D were taken as trial tests to feel out the apparatus and no great dependence can be placed on these observations because the scheme of determining the gate opening was developed later and for this reason considerable adjustment in gate area was made to accommodate the flow determined by the current meter gagings. For reasons not apparent observations 19 and 20 show gross irregularities in agreement with the plotted points of the data as a whole. For these tests the gagings were made in the narrow upstream channel section for depths of about 4.5 feet. The flow as determined by the current meter, 0.2 and 0.8 method, was 44.2 second-foot giving a mean velocity of about 4 feet per second. It is suspected that gagings made in a channel where the depth is twice the width the indicated discharge is considerably more than the actual flow. The effect of the lessened velocity along the walls of the channel is proportionally greater than for a conventional section where the width is twice the depth. To correct for this reduced velocity requires about 15 per cent correction in the observed discharge. Because of the uncertainty these two tests have been disregarded in the final analysis. It will be noted in the table that for tests 19 and 20 the Hb depth is a minimum. Careful analysis of the entire set of data does not indicate that because of the minimum depth downstream from the gate is the reason for the wide discrepancy between the current meter measurements and the computed discharge.

Two equations were taken as the law of flow through the radial measuring gate, namely $Q = CA\sqrt{2gH}$ and $Q = 1.58\ A^{1.12}$, the latter developed as the approximate mean curved through the plotted data points. The value of C being derived from the combination of these two equations. The coefficient C, shown in table 1, varies from 0.745 for the least measured discharge to 0.881 for the maximum flow. Figure 13 shows the variation of C for gate openings from 1 to 25 square feet. The gate area A was determined by applying the gate scale observation + or -, that is, where the top point of the gate is above or below the top edge of the index angle bar and applied to the diagram, Figure 14. This distance is measured by means of a portable scale. As a means of checking the discharge at any time it is only required to measure the vertical distance, with the portable scale, between the top point of the gate and the top edge of the index bar and apply this observation to the diagram, Figure 15. A copy of this diagram is posted on the door of the chart cabinet shown in Figure 8 for ready reference of discharge.

Appended is the drawing showing the arrangement of the installation and details of the float control instrument, recording instrument and other features. Also the wiring diagram of the electrical control panel and copy of the record chart.

ACKNOWLEDGMENT

The Pueblo Water District, No. 2, provided the funds covering the major items of the installation such as the instrument shelter, radial gate, motor equipment and control, labor, and other items of expense, through the most cordial cooperation of Superintendent Fred Dunlap.

The necessary field engineering, design of shelter, and other required assistance relating to the installation of the equipment was provided by S. F. Elliot, Consulting Engineer and his staff, with offices at Pueblo.

The current meter gagings made for calibrating the measuring gate were made by [illegible] Burgess, Chief Hydrographer of the State Engineer's Office, Denver, Colorado.

The expert assistance given by the mechanics and others, employed by the Water Company, was greatly appreciated.

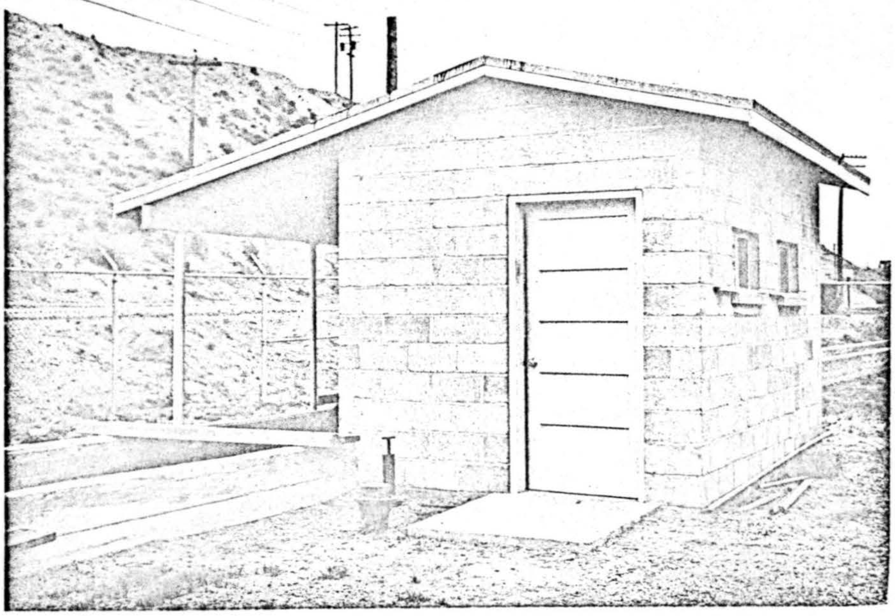


Fig. 1 Instrument shelter house showing adjacent concrete lined supply channel. At the left corner of building note the index bar attached to roof support.

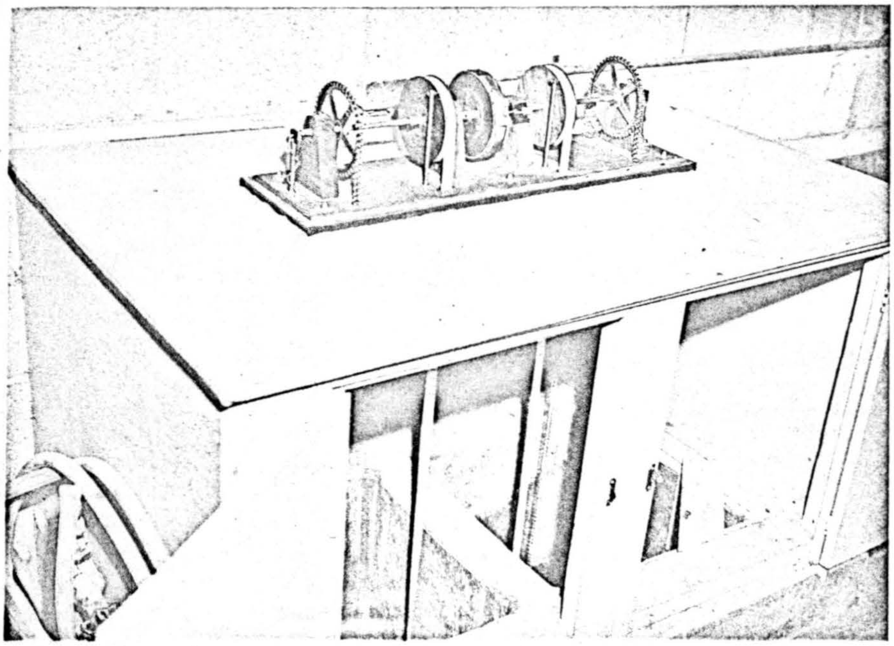


Fig. 2 Float control instrument. The graduated white tapes on disks indicate the water depths, Ha and Hb, above the sill of the radial gate.

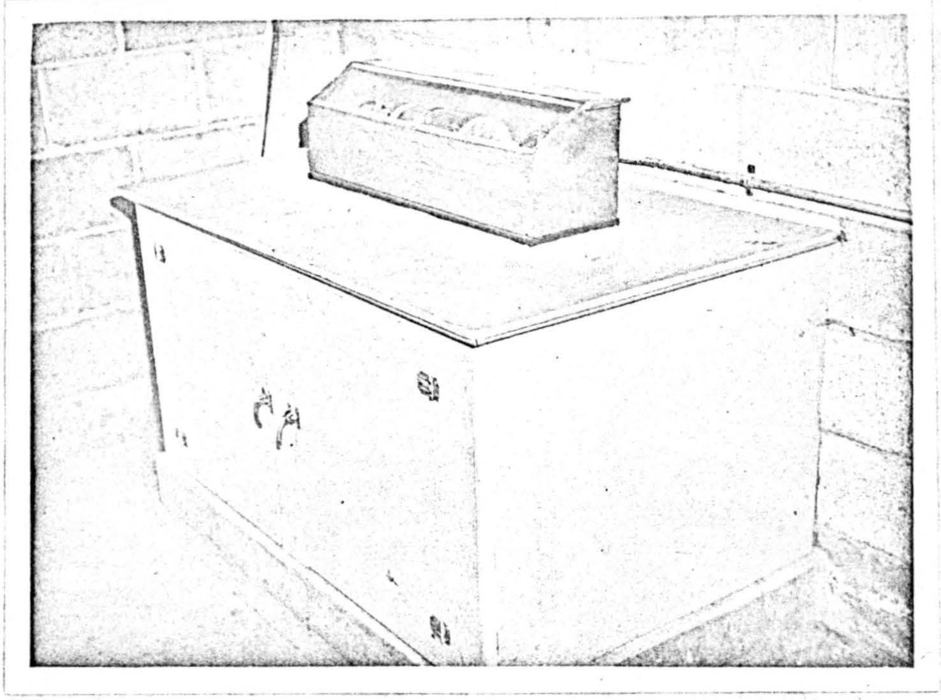


Fig. 3 Float control instrument, with cover in place, mounted on cabinet.

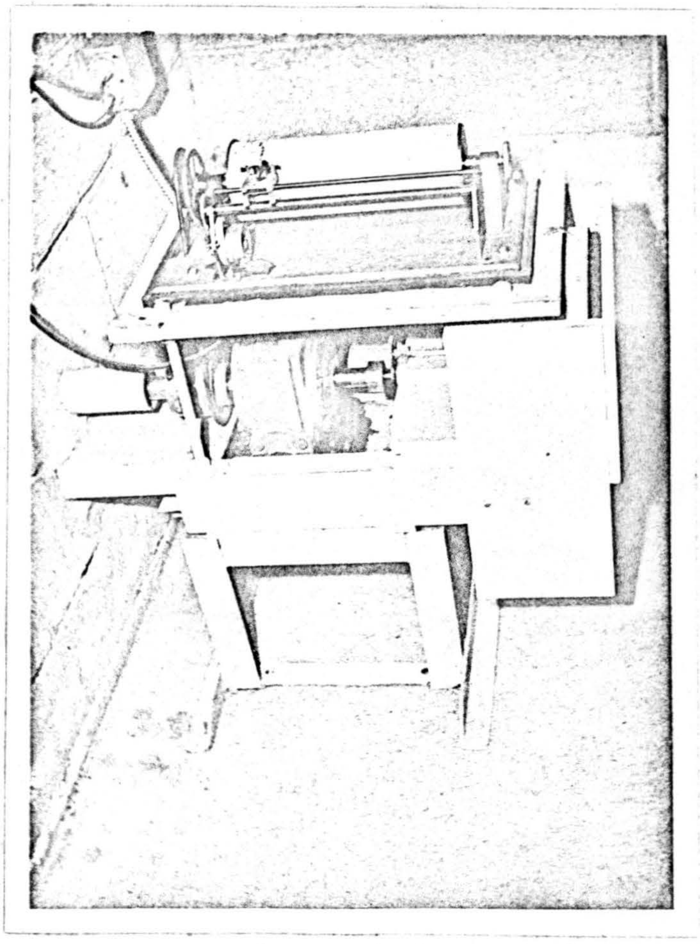


Fig. 4 Recording instrument mounted on platform above motor assembly. Discharge indicating disk at right.

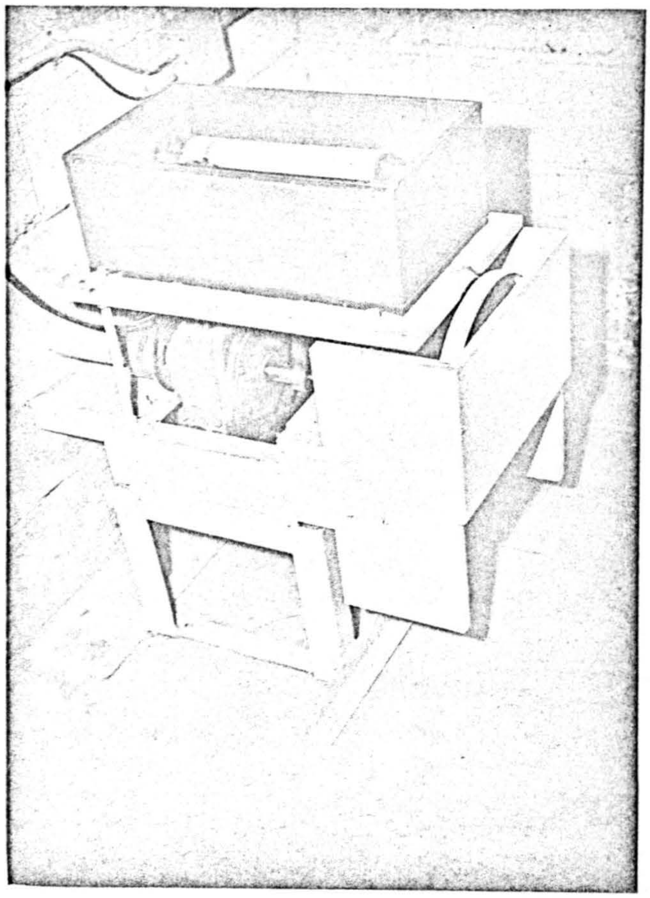


Fig. 5 Recording instrument with cover in place.

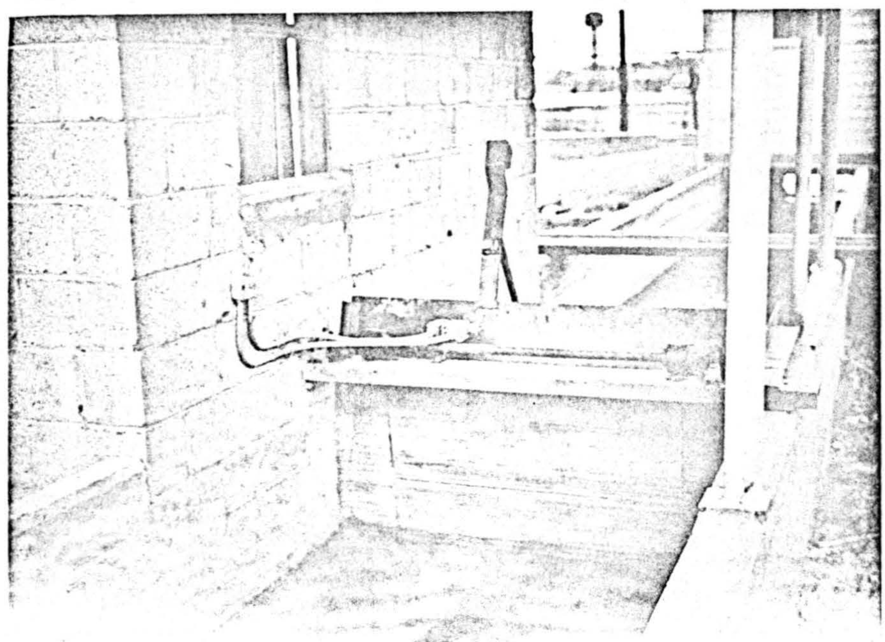


Fig. 6 Upstream face of measuring gate. The projection at top of gate serves as the trip for the limit switch. The other trip is on face of gate submerged beneath water surface. Index angle bar at right of gate.

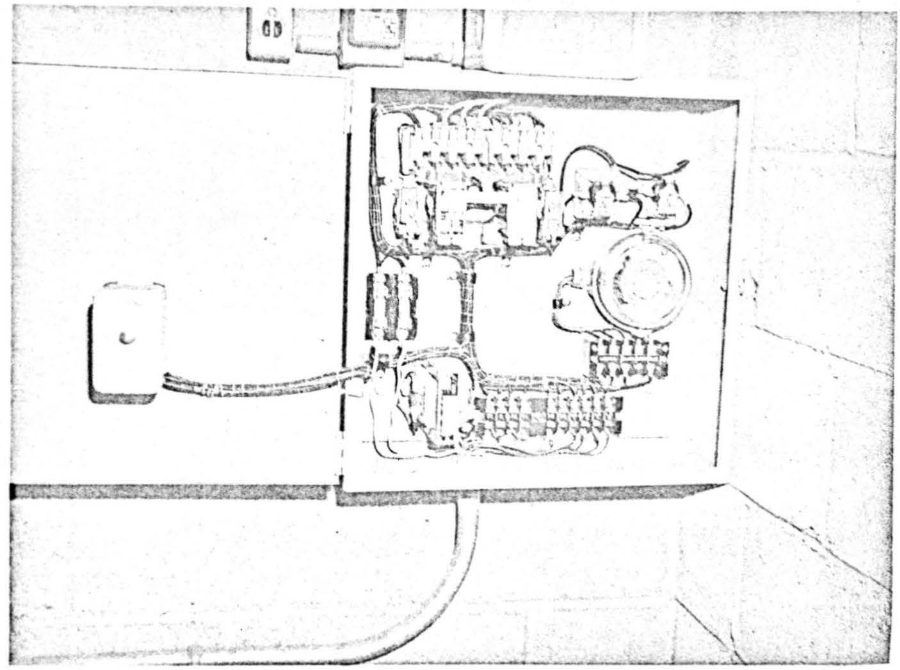


Fig. 7 Electric control panel, door open, that regulates the movement of the radial gate. Wiring diagram appended to report.

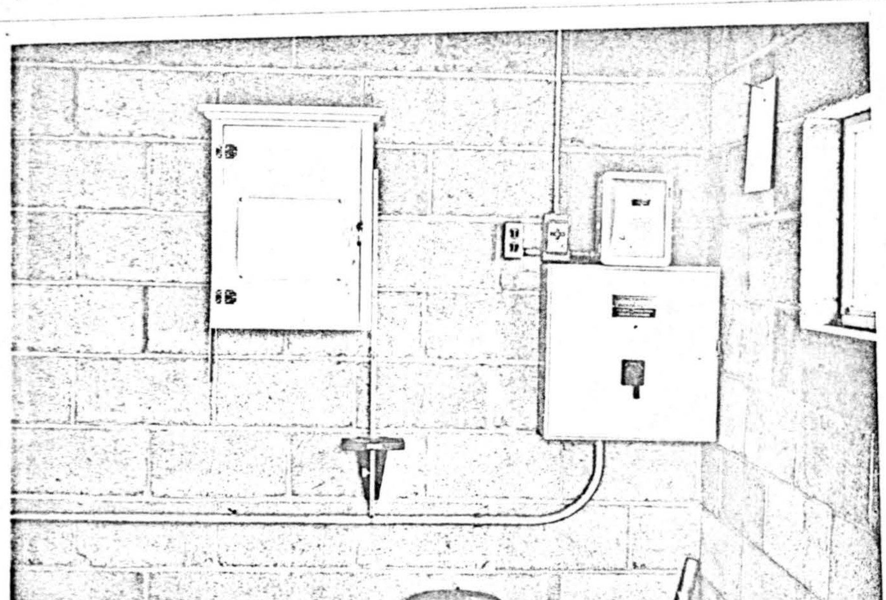


Fig. 8 Control panel with door closed to show handle for automatic and manual operation of motor. Chart cabinet at left. Index bar scale-flow diagram posted on door of cabinet for ready reference to discharge.

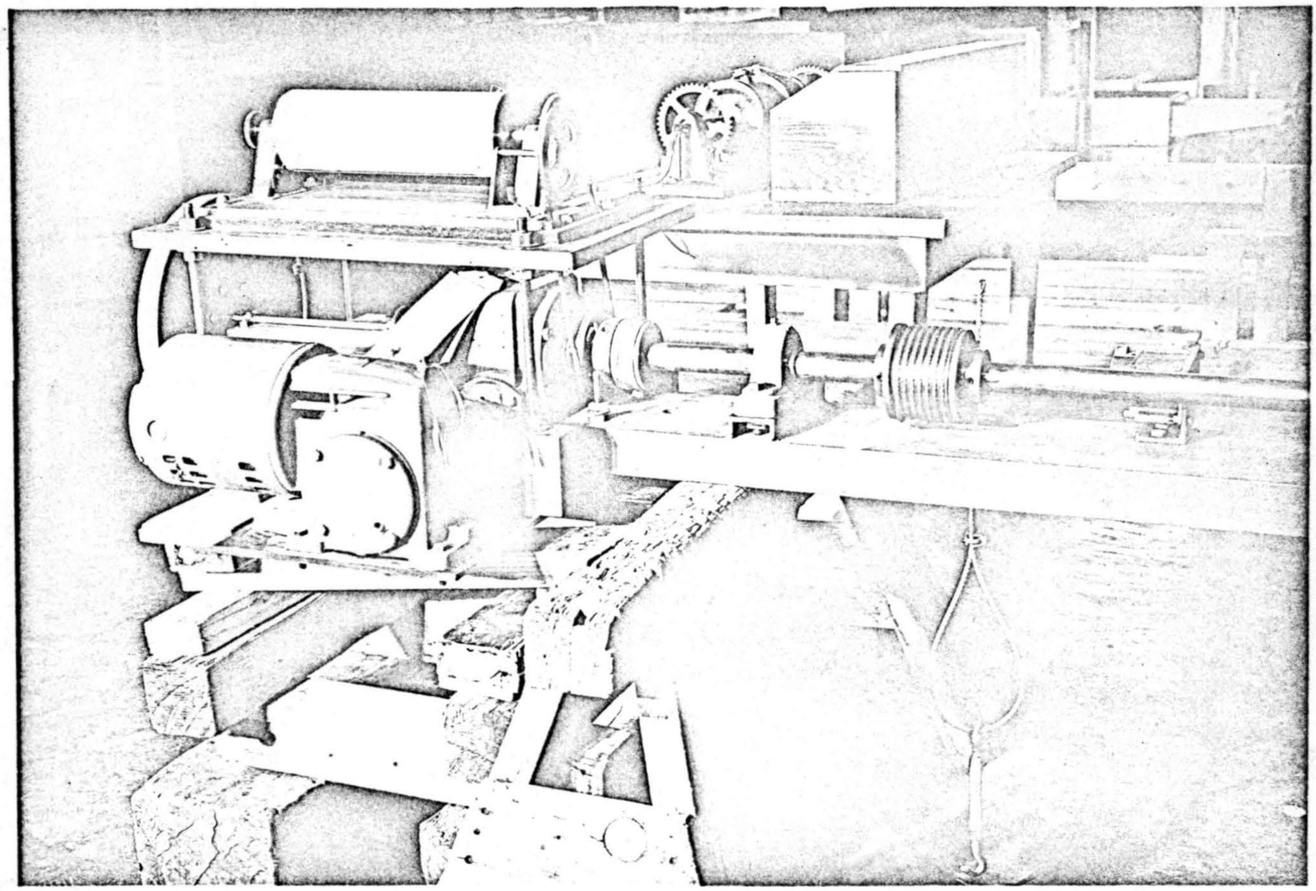


Fig. 9 Shop assembly to show motor drive and recording instrument, also $1\frac{1}{4}$-inch steel shaft with cable drum for gate lift, 3/16-inch high tensile steel cable.

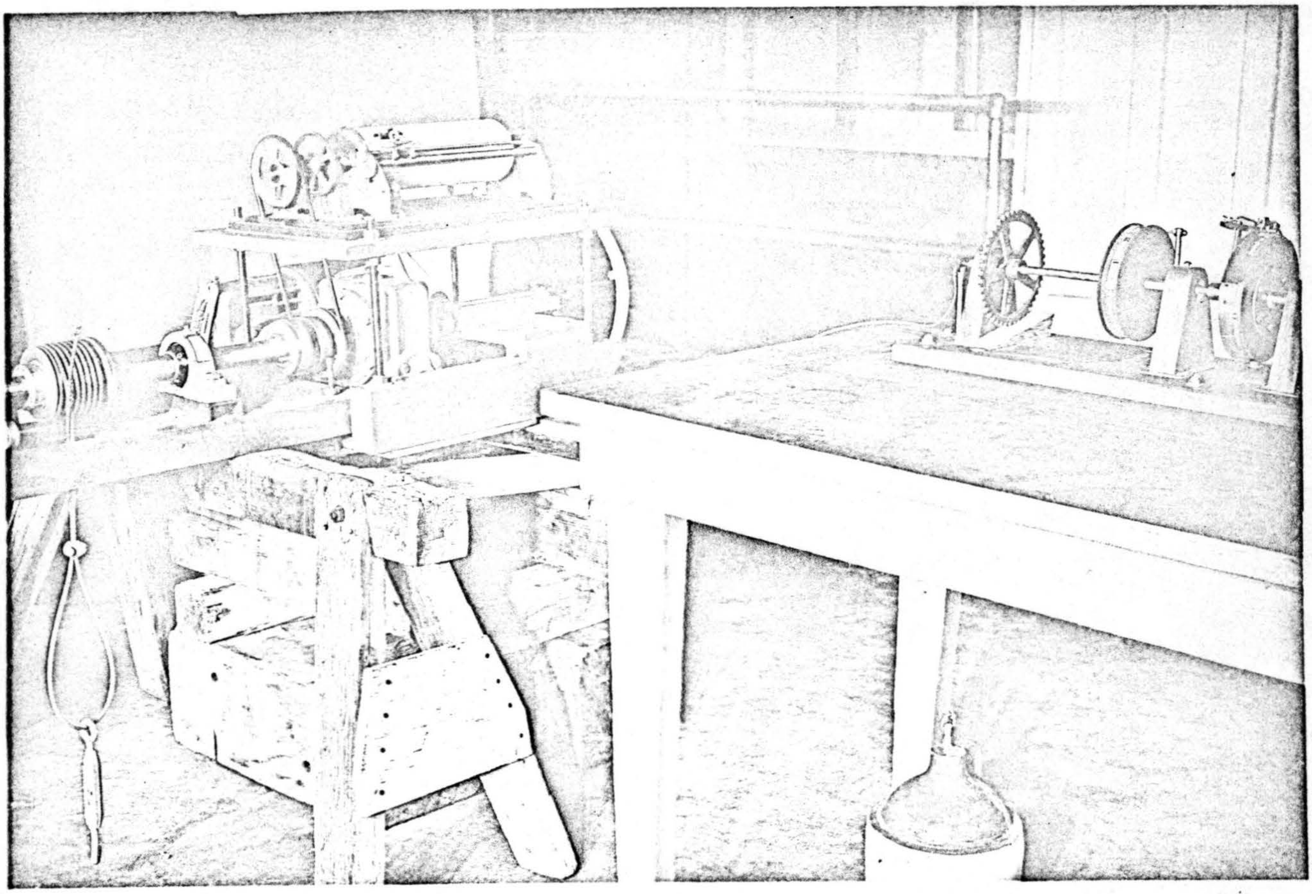


Fig. 10 Shop assembly to show motor drive, recording instrument and discharge indicating disk at right, also $\frac{1}{4}$-inch round leather belt drive that operates chart cylinder. One-gallon whisky pottery jug float at lower right.

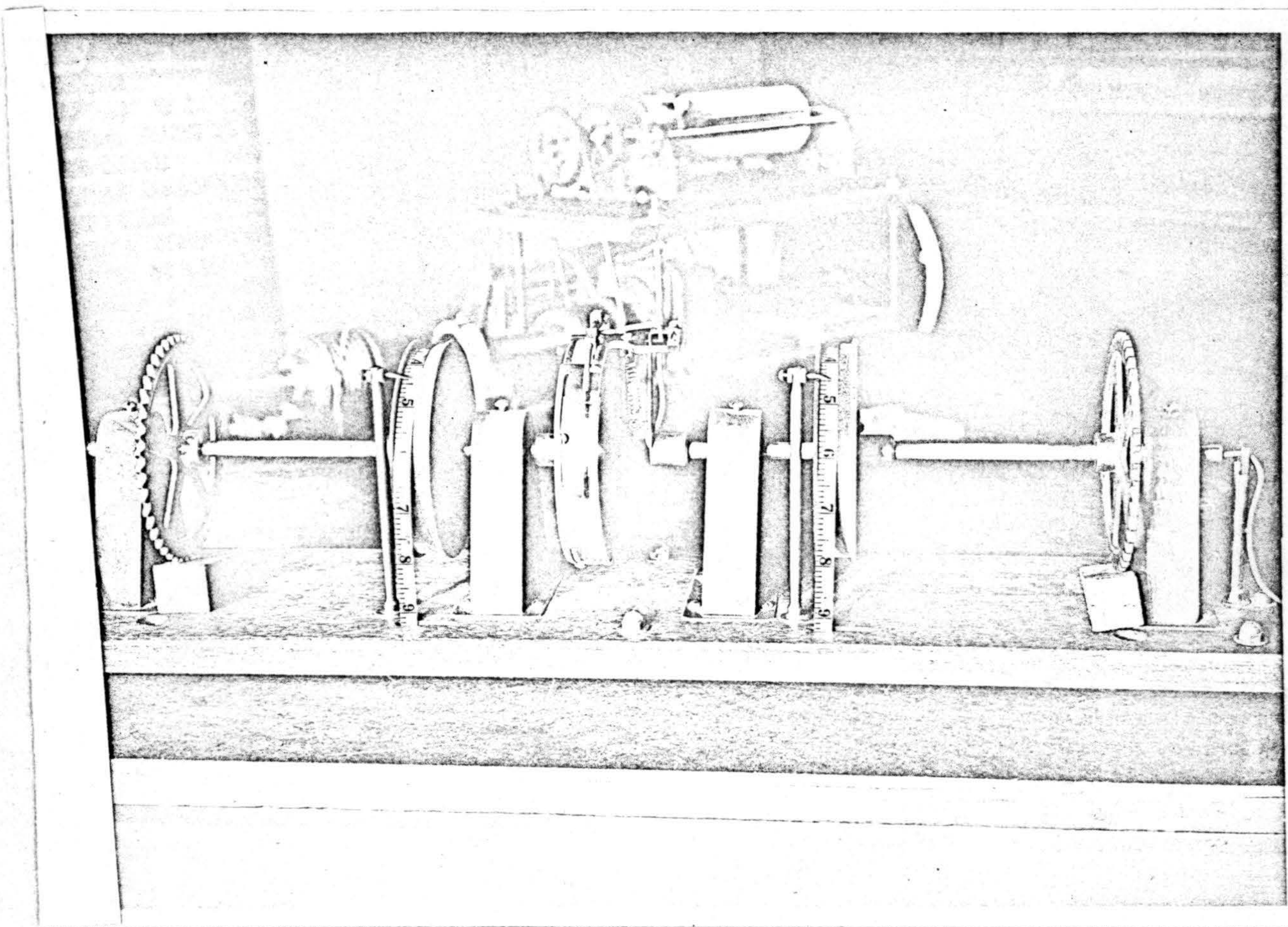


Fig. 11 View of float control instrument showing lead wires into hollow shafts, depth indicating disks, index pointers and sprockets for No. 2 brass ladder float chains. Center disk is the contact mechanism.

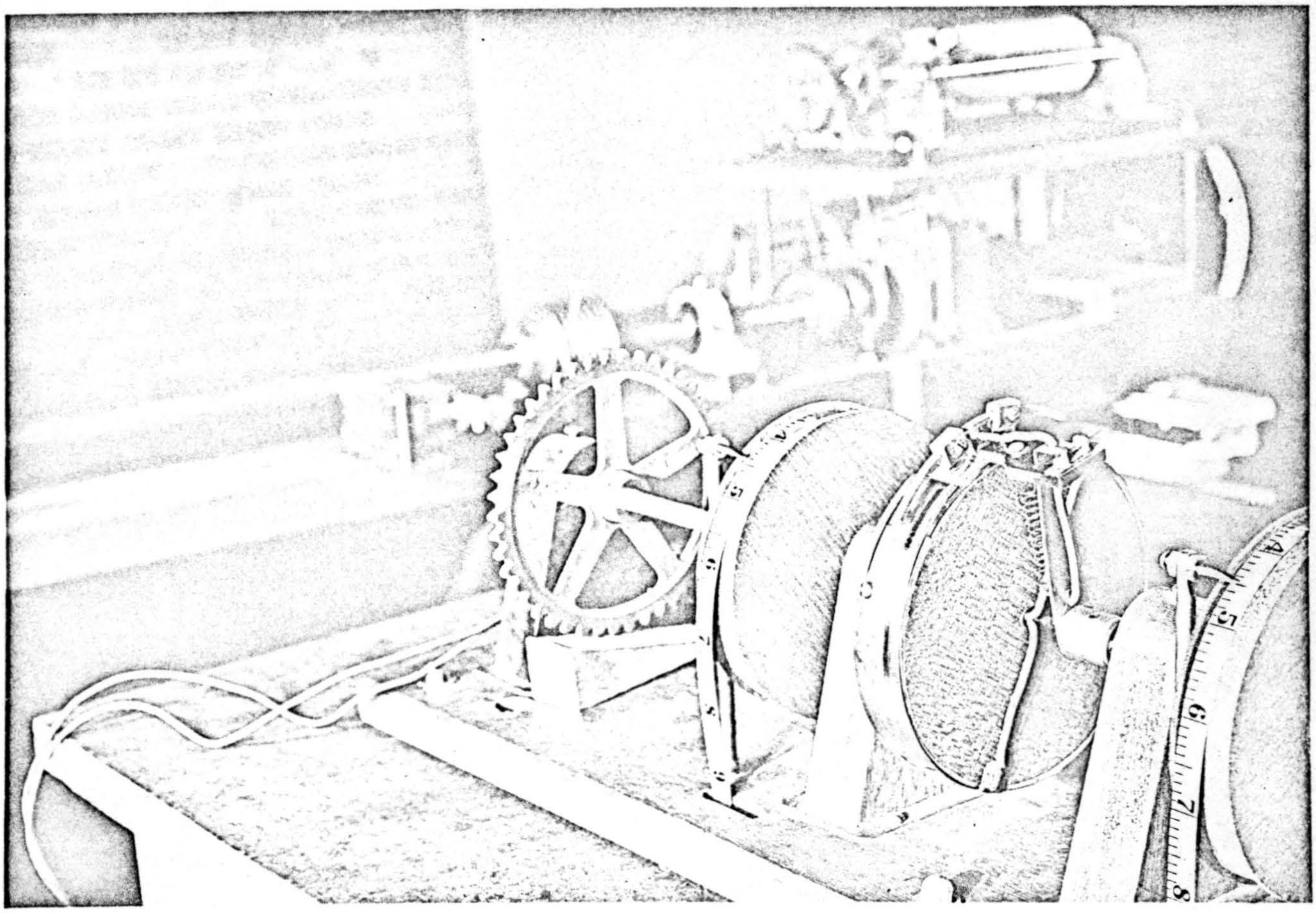
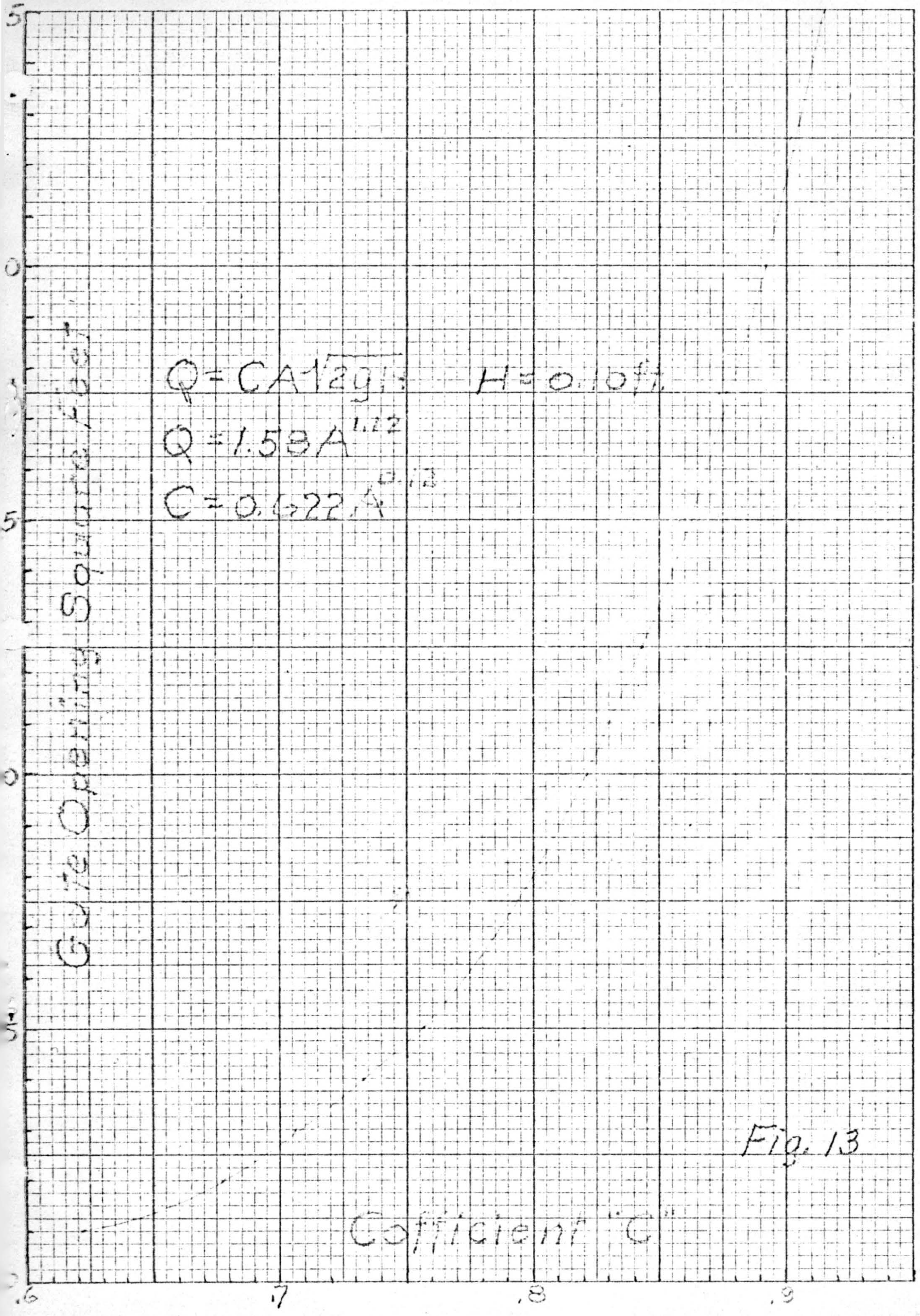


Fig. 12 View showing lead wires to contact plates on disk and the movable block at top, silver contact points, operated by the Ha float.


Q = CA√2gH   H = 0.10 ft.
Q = 1.58A^1.12
C = 0.622A^0.12
Gate Opening Square Feet
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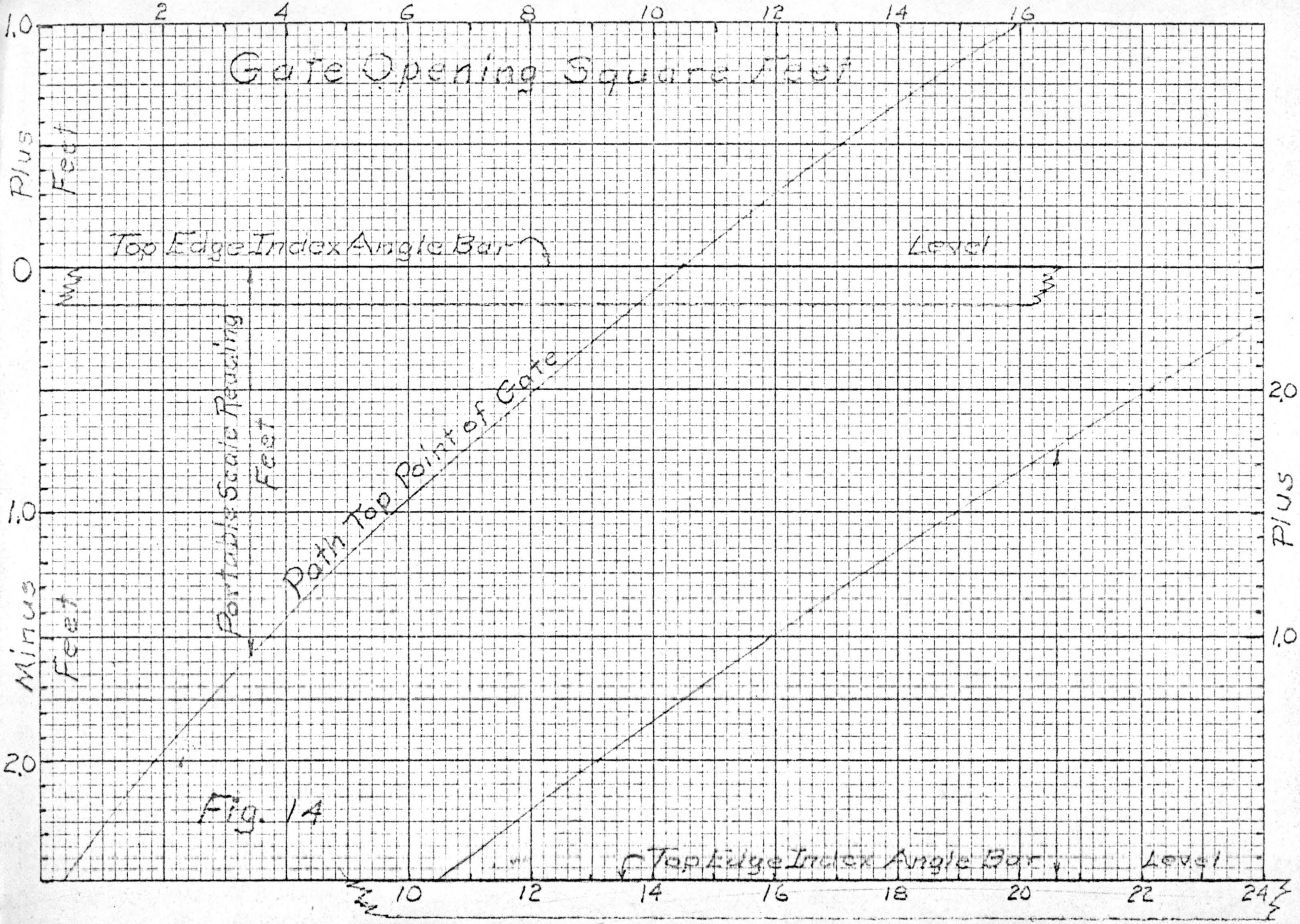
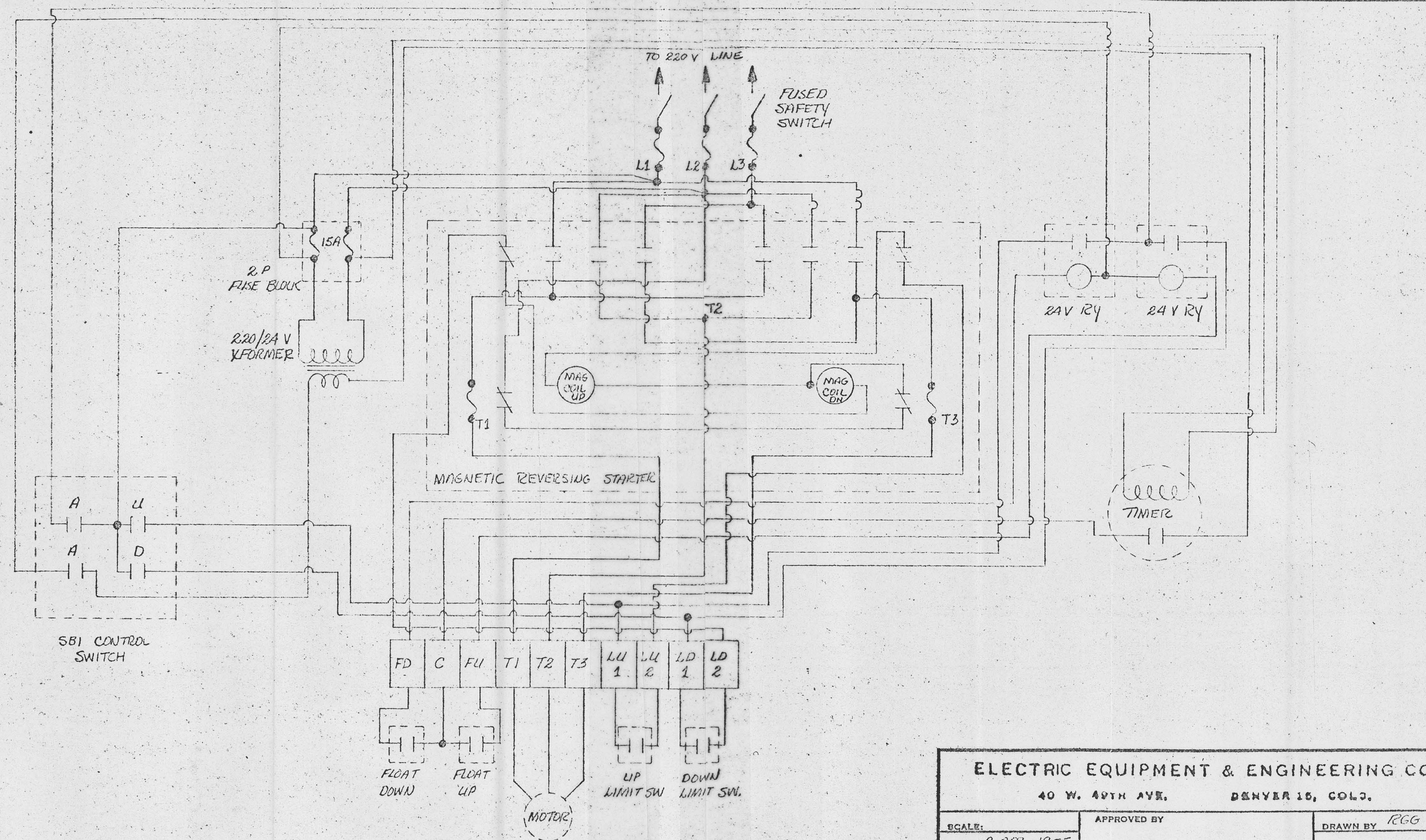
.6
.7
.8
.9
5
0
5
0

Fig. 13



2
4
6
8
10
12
14
16
1.0
Gate Opening Square Feet
Plus
Feet
Top Edge Index Angle Bar
Level
0
Portable Scale Reading
Feet
Path Top Point of Gate
20
1.0
Plus
Minus
Feet
1.0
2.0
Fig. 14
Top Edge Index Angle Bar
Level
10
12
14
16
18
20
22
24



ELECTRIC EQUIPMENT & ENGINEERING CO 40 W. 49TH AVE. DENVER 16, COLO.		
SCALE: DATE: 2 APR 1955	APPROVED BY	DRAWN BY RGG REVISED
WIRING DIAGRAM - FLOAT CONTROL CABINET - FOR RALPH PARSHALL - CITY OF PUEBLO		
		DRAWING NUMBER 6-356

11X17 PRINTED ON NO. 1000H CLEARPRINT

STATION

ON------ A.M. P.M. Mo.------ DAY---- 19----

PUEBLO WATER WORKS DIST. NO. 2

OFF------ A.M. P.M. Mo.------ DAY---- 19----

DISCHARGE -------- CU. FT. SEC.

SOUTH SIDE INTAKE AT DIVERSION DAM

DISCHARGE -------- CU. FT. SEC.

CUBIC 10 FEET 20 PER 30 SECOND 40

NOON

NOON

NOON

NOON

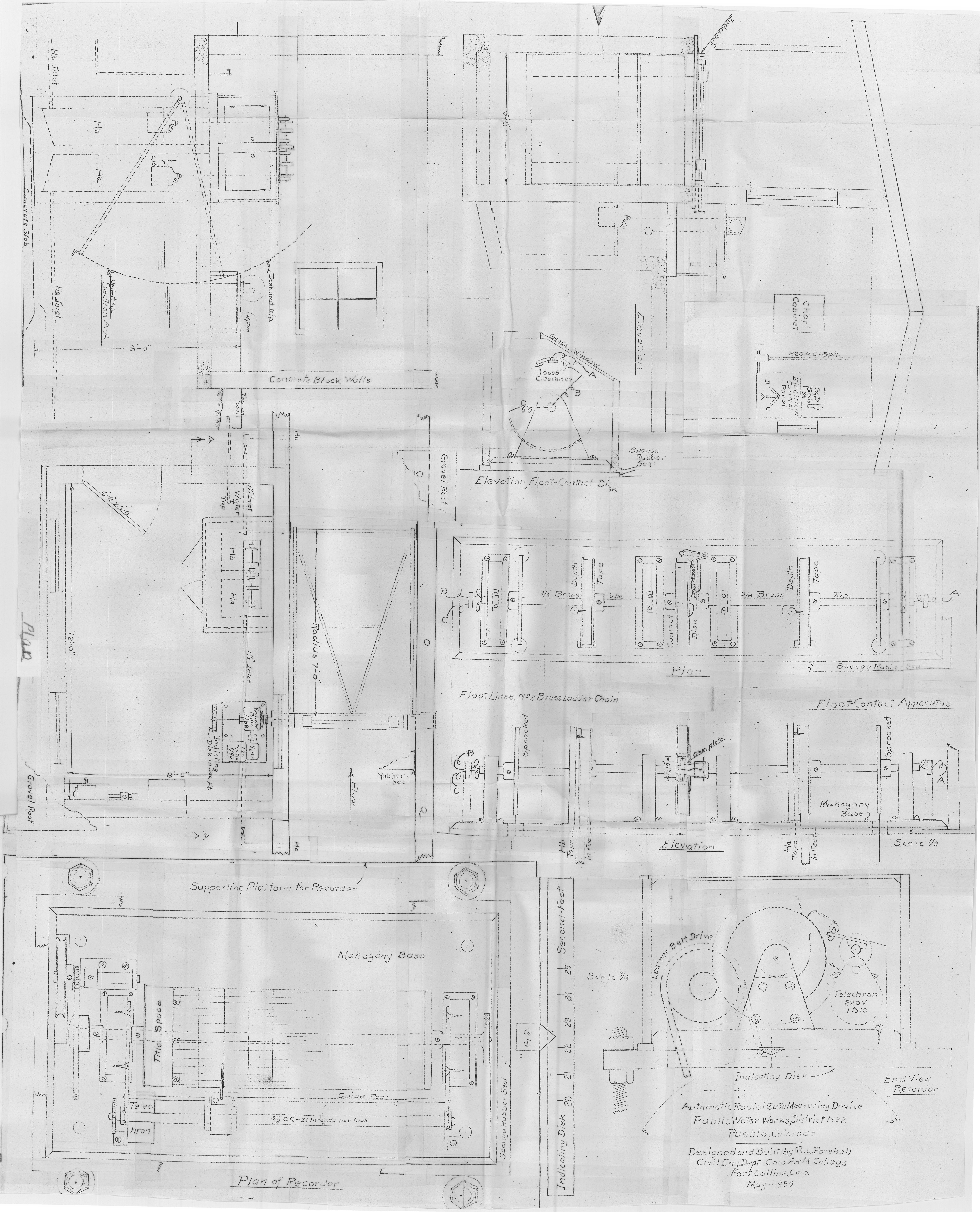
NOON

NOON

NOON

NOON

10 20 30 40



Hb Inlet
Hb
Ha
Concrete Slab
Ha Inlet
Section A-A
Down limit
8'-0"
Concrete Block Walls
Elevation
Indexbar
5'-0"
Chart Cabinet
220 AC-3 ph.
Electrical Control Panel
Glass Window
.0005" Clearance
Sponge Rubber Seal
Elevation, Float-Contact Disk
Gravel Roof
6'-8"x3'-0"
Water Tap
1/2" Inlet
Plan
12'-0"
Radius 7'-0"
Indicating Disk in Sec. Ft.
Flow
Rubber Seal
8'-0"
3/8 Brass Tube
Depth Tape
Contact Disk
Sponge Rubber Seal
Float Lines, No2 Brass Ladder Chain
Float-Contact Apparatus
Sprocket
Glass plate
Mahogany Base
Hb Tape in Feet
Ha Tape in Feet
Elevation
Scale 1/2
Supporting Platform for Recorder
Mahogany Base
Title Space
Guide Rod
3/8 CR-26 threads per inch
Telechron
Sponge Rubber Seal
Plan of Recorder
Second-Feet
Indicating Disk
Scale 3/4
Leather Belt Drive
Telechron 220V 1 to 10
Indicating Disk
End View Recorder
Automatic Radial Gate Measuring Device
Public Water Works, District No2
Pueblo, Colorado
Designed and Built by R. L. Parshall
Civil Eng. Dept. Colo. A&M College
Fort Collins, Colo.
May-1955