HYD 216

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

CALIBRATION OF THE CONSTANT-HEAD ORIFICE TURNOUT

1 TO 2 SCALE MODEL

Hydraulic Laboratory Report No. Hyd.-216

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

NOVEMBER 25, 1946

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
November 25, 1946

Laboratory Report No. 216
Hydraulic Laboratory
Compiled by: B. R. Blackwell
Checked by: H. M. Martin

Subject: Calibration of the constant-head orifice turnout—One to two scale model.

INTRODUCTION

The constant-head orifice turnout has become an increasingly popular device for the diversion, control, and measurement of canal flow into laterals. Although several hundred of these turnouts have been constructed for such projects as Altus, Mirage Flats, Buford-Trenton, Buffalo Rapids, and Tucumcari from the standard designs as shown on Bureau of Reclamation Drawings Nos. 40-D-3672 and 40-D-3673 (Figures 1 and 2 in this report) the device has never been calibrated. The temporary discharge tables included on the drawings are based on an assumed coefficient of approximately 0.66 in the following equation:

$$Q = CA\sqrt{2gH}$$

where Q = discharge in second-feet
H = differential head on the orifice gate = 0.2 foot
A = area of the orifice gate opening in square feet
C = the coefficient of discharge
g = acceleration due to gravity

The constant-head orifice is operated as follows: The orifice gate opening for the desired discharge is obtained from the discharge table. With the orifice gates set at this opening, the turnout gates are adjusted until the differential head on the orifice gates, as read on the weir gages, is at the required constant head of 0.2 foot. The discharge is now at the desired value. Figure 3 shows a single-barrel constant-head orifice turnout in operation on the Tucumcari Project in New Mexico.

Calibration of the constant-head orifice turnout was made in the Hydraulic Laboratory in Denver, using a 1 to 2 scale model. A total of 98 tests were made on six different designs of turnouts at various gate openings and canal water surface elevations. Discharge coefficients were obtained and discharge tables prepared.

THE MODEL

The model (1 to 2 scale) was constructed of timber and lined with sheet metal and included the complete constant-head orifice turnout and a short section of canal bank with a 1-1/2 to 1 slope. The various designs studied are shown in Figures 1 and 2. The 20 second-foot capacity, double barrel, Plan 1 design was constructed first. The other designs were obtained by modifying this first installation. The 20 second-foot capacity, double barrel, Plan 3 installation is shown in Figure 4.

In the model the heads on the orifice gate were measured by piezometers connected to a manometer board.

The water in the model was measured with three devices having overlapping discharge ranges: (1) 1.5-inch flow nozzle, (2) 6.5-inch A.S.M.E. meter, and (3) 8-inch B.I.F. venturi meter. These meters have been calibrated at intervals using the laboratory volumetric tank. Recalibration at this time was not necessary.

THE INVESTIGATION

The model was operated by setting the orifice gate and adjusting the discharge and the turnout gates to obtain tests covering the desired range of water surface elevation in the canal with approximately 0.10-foot (0.20-foot prototype) differential head on the orifice gate. Where necessary, the model discharge was adjusted to 0.10-foot differential head assuming the discharge proportional to the square root of the head.

The 20-second-foot capacity turnout. Tests on Plan 1, double barrel design with uniform gate openings, showed that the discharge coefficient was essentially constant for a given gate opening for various canal water surface elevations but increased slightly with increased gate openings up to a prototype gate opening of 1.5 feet (Figure 5). For larger gate openings the coefficient increased appreciably with an increase in the gate opening as well as varying with the canal water surface elevation. The same results were obtained in Plans 2, 3, and 4. Water surfaces in Plans 1 and 2 were relatively smooth and flow conditions steady. Plan 3 gave somewhat rougher conditions. Plan 4 gave the poorest operation, although the coefficient of discharge averaged the same as for the other plans. Surges in the stilling-pool made the differential head hard to read. Water boiling up in front of the turnout gates resulted in a tilted water surface in the stilling-pool.

Operation with only one of the two gates open gave satisfactory coefficients for small gate openings when the turnout gate below the opened orifice gate was used and with the downstream weir gage located on the sidewall next to the open gates. Incorrect heads were measured when the downstream weir gage was located on the sidewall opposite the open gates or when both turnout gates were opened with only one orifice gate. More consistent results were obtained when the downstream weir gage was located adjacent to the orifice gate instead of adjacent to the

turnout gate. Operation of one gate of two is not desirable because of the difficulties in obtaining the correct differential head due to the rough and tilted water surface between the orifice gate and the turnout gate.

The single barrel type gave similar operation to the double barrel type and the same discharge coefficients.

The 20-second-foot capacity turnout is designed to operate with the canal water surface from 2 feet 3 inches to 6 feet above the orifice gate seat. Depth greater than 6 feet will not effect the coefficient of discharge. The minimum satisfactory depth must fulfill two conditions; (1) the orifice gate opening must be completely submerged, and (2) the water surfaces must be smooth enough to satisfactorily read the weir gages. The model indicated that a 2-foot prototype depth is about the lowest satisfactory depth at maximum gate opening. For smaller gate opening this minimum depth could be reduced.

The 10-second-foot capacity turnout. Due to the consistency of results for the various plans of the 20-second-foot capacity turnout, only Plan 2 of the various 10-second-foot capacity turnouts was tested. The coefficient of discharge for gate openings up to 1.05 feet prototype were essentially the same as for the 20-second-foot capacity turnouts. For larger gate openings the coefficient increased appreciably with an increase in gate opening as well as varying with the canal water surface elevation.

The 10-second-foot capacity turnout is designed to operate with the canal water surface from 21 inches to 6 feet above the orifice gate seat. Greater depth will not effect the coefficient. Minimum operating depth as indicated by the model for maximum gate opening is about 18 inches.

PREPARATION OF DISCHARGE TABLES

The coefficient of discharge varied from 0.685 at a gate opening of 0.06 foot to 0.715 at a gate opening of 1.6 feet. A coefficient versus gate opening plot was made by averaging the tests for each gate opening. A straight line was drawn through the points (Figure 5). From this coefficient curve discharges were computed and a discharge versus gate opening curve plotted. Values in the discharge tables giving the gate opening for every one-half second-foot of discharge were obtained from the discharge versus gate opening curves. Discharge and gate opening tabulations are given in Table 1 for the 20-second-foot capacity constant-head orifice turnout and in Table 2 for the 10-second-foot capacity turnout.

TABLE 1

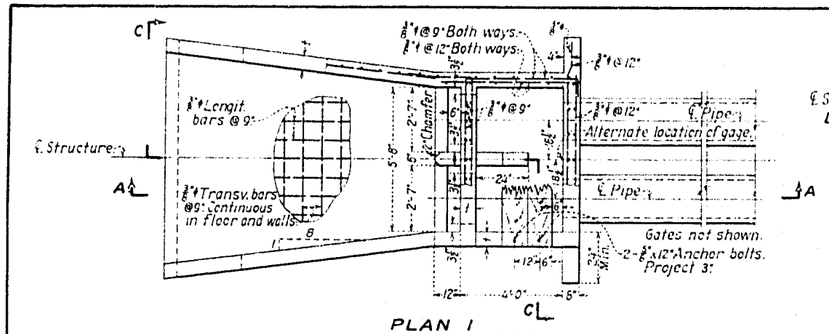
Discharge tables for the constant-head orifice turnout. Capacity 20 second-feet, gate size 24 inches by 30 inches

Discharge Second-feet	Gate opening in feet		Discharge second-feet	Gate opening in feet	
	2 gates	1 gate		2 gates	1 gate
0.5	0.04	0.08	10.5	0.83	
1.0	0.08	0.16	11.0	0.87	
1.5	0.12	0.24	11.5	0.91	
2.0	0.16	0.32	12.0	0.95	
2.5	0.20	0.40	12.5	0.99	
3.0	0.24	0.48	13.0	1.03	
3.5	0.28	0.56	13.5	1.07	
4.0	0.32	0.64	14.0	1.10	
4.5	0.36	0.72	14.5	1.14	
5.0	0.40	0.79	15.0	1.18	
5.5	0.44	0.87	15.5	1.22	
6.0	0.48	0.95	16.0	1.26	
6.5	0.52	1.03	16.5	1.30	
7.0	0.56	1.10	17.0	1.34	
7.5	0.60	1.18	17.5	1.37	
8.0	0.64	1.26	18.0	1.41	
8.5	0.68	1.34	18.5	1.45	
9.0	0.72	1.41	19.0	1.49	
9.5	0.76	1.49	19.5	1.53	
10.0	0.79	1.56	20.0	1.56	

TABLE 2

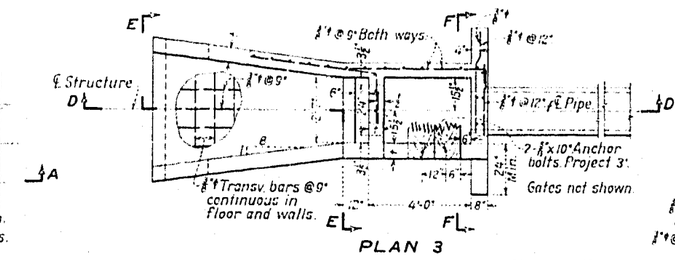
Discharge tables for the constant-head orifice turnout. Capacity 10 second-feet, gate size 18 inches by 24 inches

Discharge second-feet	Gate opening in feet	
	2 gates	1 gate
0.5	0.05	0.10
1.0	0.10	0.20
1.5	0.15	0.30
2.0	0.20	0.40
2.5	0.25	0.50
3.0	0.30	0.60
3.5	0.35	0.70
4.0	0.40	0.79
4.5	0.45	0.89
5.0	0.50	0.99
5.5	0.55	
6.0	0.60	
6.5	0.65	
7.0	0.70	
7.5	0.74	
8.0	0.79	
8.5	0.84	
9.0	0.89	
9.5	0.94	
10.0	0.99	

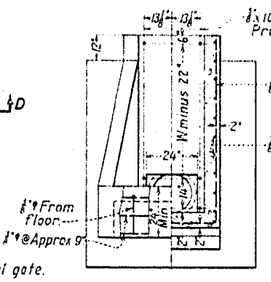


PLAN 1

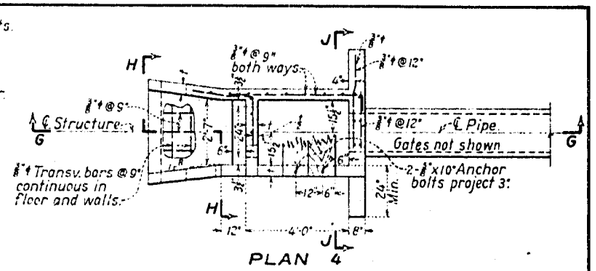
SHOWING REINFORCEMENT FOR 1-7' DOUBLE BARREL ONLY



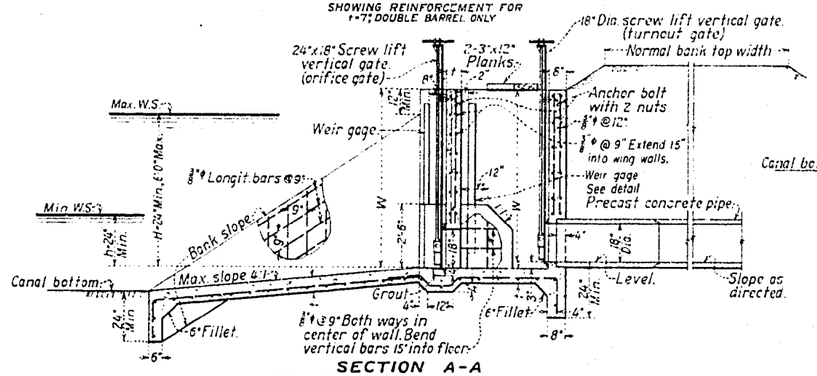
PLAN 3



SECTION E-E

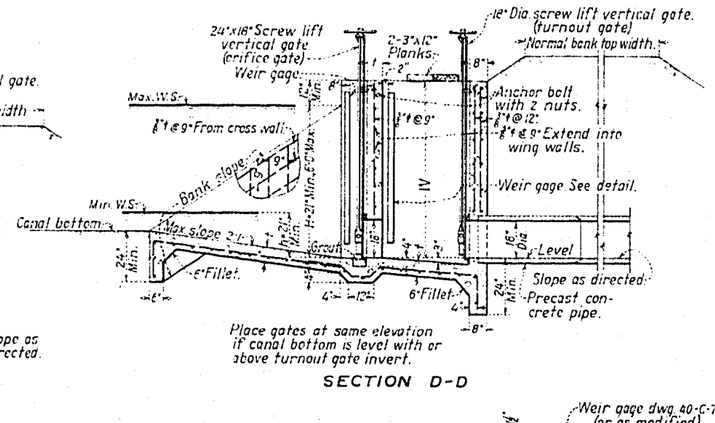


PLAN 4

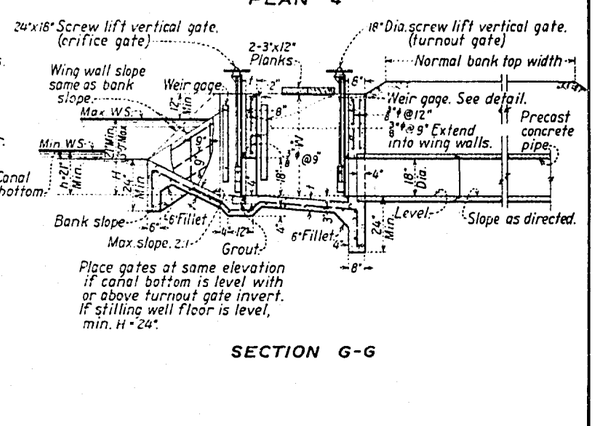


SECTION A-A

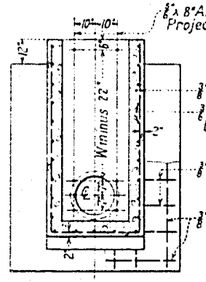
WHERE INLET FLOOR SLOPE EXCEEDS 4:1, SEE PLAN 2



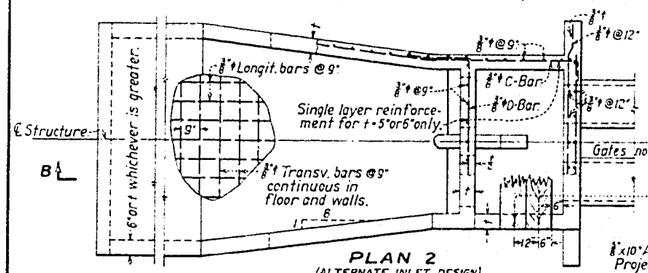
SECTION D-D



SECTION G-G

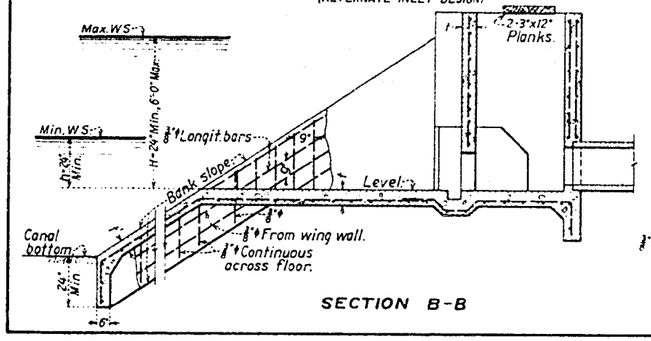


SECTION F-F

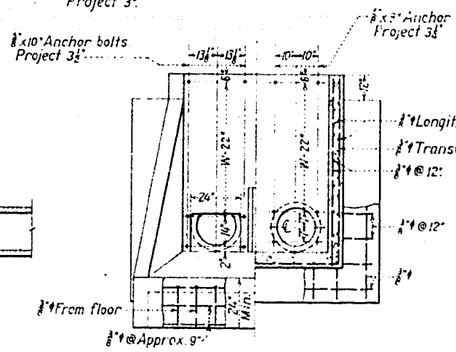


PLAN 2

(ALTERNATE INLET DESIGN)



SECTION B-B

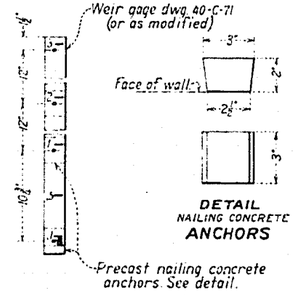


SECTION C-C

INLET WALLS AND FLOOR THICKNESS AND REINFORCEMENT

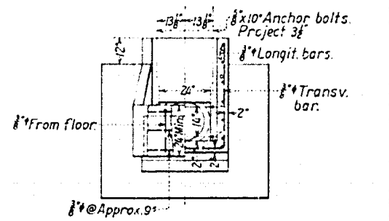
H	t	t'	REINFORCEMENT AS SHOWN EXCEPT AS NOTED BELOW
21" to 4'-0"	5"	5"	C and D-bars @ 9" (Plan 2)
4'-3" to 5'-3"	6"	5"	C and D-bars @ 6" (Plan 2)
5'-6" to 6'-0"	7"	6"	See Plans 1 and 3

SCALE OF FEET 0 1 5

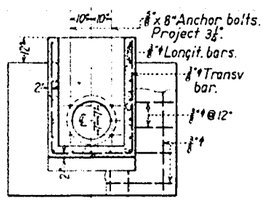


DETAIL NAILING CONCRETE ANCHORS

DETAILS OF GAGE



SECTION H-H



SECTION J-J

GAGE SETTING

(VERTICAL DIMENSIONS)

H.	NORMAL GAGE LENGTH	HEIGHT OF ZERO OF GAGE ABOVE ORIFICE GATE SILL
*a+(0 or 3")	*a	6"
*a+(6" or 9")	*a+1 Ft.	0"

*a = 1, 2, 3; -6" AS REQUIRED

OPERATION OF ORIFICE GATE

WITH LOSS OF 0.2' OF HEAD

QUANTITY SEC. FT.	APPROX ORIFICE GATE OPENING
1	.20'
2	.40'
3	.60'
4	.79'
5	.99'

For any desired Q set orifice gate at opening shown (or as determined by calibration) and adjust turnout gate to obtain a difference of 0.20 ft. in the gage readings.
Discharge shown is for one gate only
Use both gates on 2-bay structure.

NOTES

All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete, unless otherwise shown.
Lap all bars 34 diameters at splices.
Provide head in addition to that required for operation of orifice gate to cover losses through turnout gate and pipe. Where sufficient head is available turnout pipe and gate may be made smaller as directed.
Zero point of both gages to be set at same elevation.
Establish W in 3" increments begining at 2'-9"
Plans 1 and 2 may be adapted to single barrel structures, and Plans 3 and 4 to double barrel structures within limits of operating head requirements.
For outlet transitions and collars, use Dwgs. 40-D-564, and 40-D-565 with modified pipe spacing.
t = thickness of walls, floor, and cross wall of inlet.
t' = thickness of apron of alternate inlet design.
H = head on orifice gate sill. Max. 6'-0", Min. 21"
H' = head on turnout gate sill, no flow, = H or H minus 3"
h = min. head on orifice gate sill measured from min. water surface assumed in canal for full delivery to lateral.
For H of 3'-0" or less use orifice gate Dwg. 40-D-3717 and turnout gate Dwg. 40-D-3704.
For H of 3'-3" to 6'-0" use orifice gate Dwg. 40-D-3701, and turnout gate Dwg. 40-D-3699.

REV. MAY 11, 1965 — 12-26-45 — 1-15-47

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER OFFICE

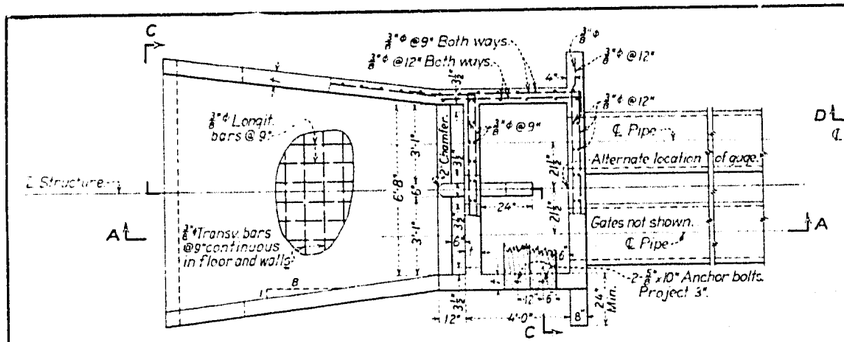
CONSTANT HEAD ORIFICE TURNOUT

MAX. CAPACITY 10 SECOND FEET

DRAWN: D.G.T.-L.B.H. SUBMITTED:
TRACED: J.J.A. RECOMMENDED:
CHECKED: H.H. E.R.B. APPROVED:

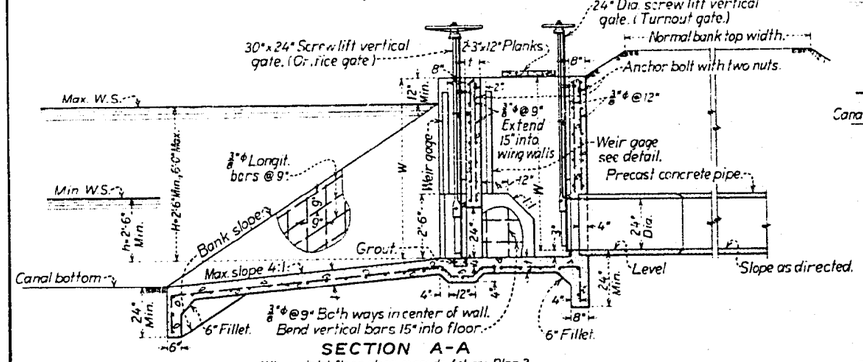
DENVER, COLORADO, MARCH 24, 1947

40-D-3672



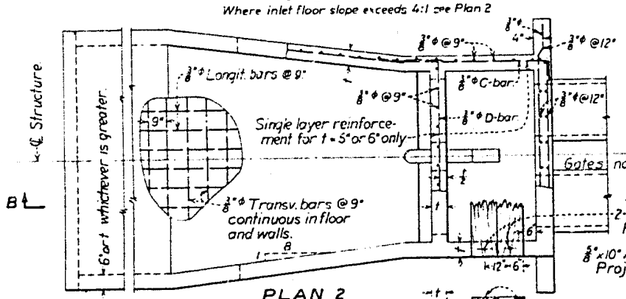
PLAN 1

Showing reinforcement for t=7", double barrel only.



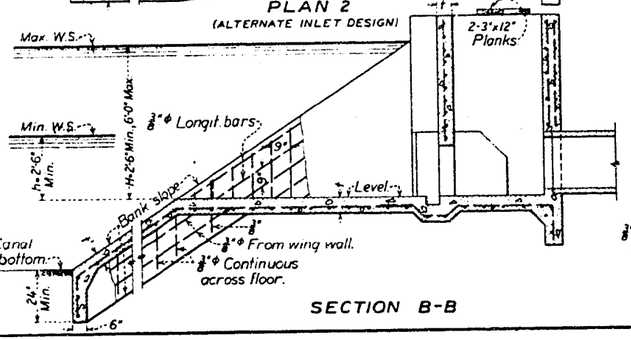
SECTION A-A

Where inlet floor slope exceeds 4:1 see Plan 2

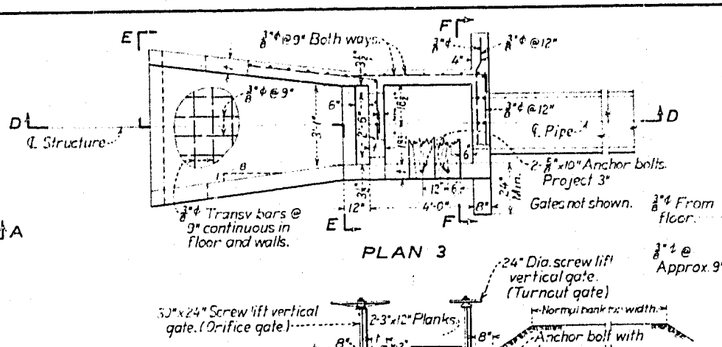


PLAN 2

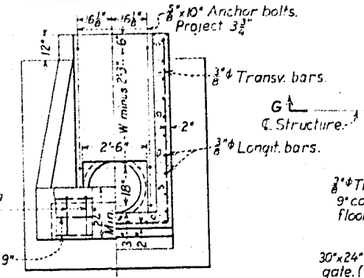
(ALTERNATE INLET DESIGN)



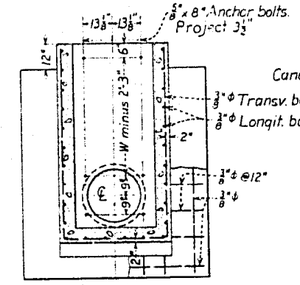
SECTION B-B



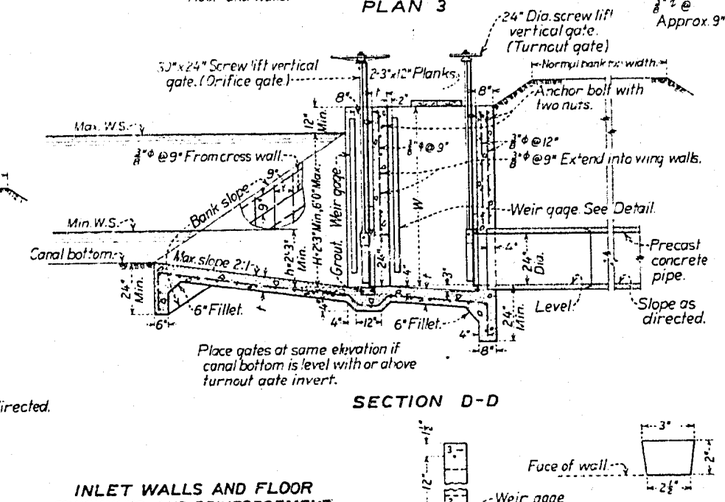
PLAN 3



SECTION E-E



SECTION F-F



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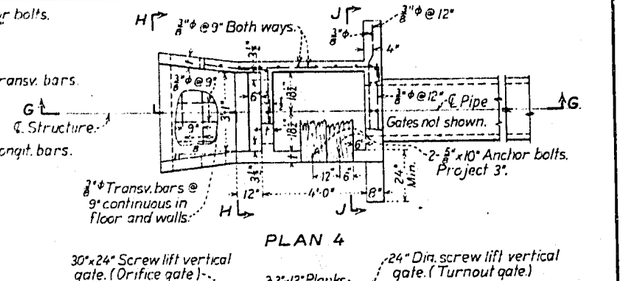
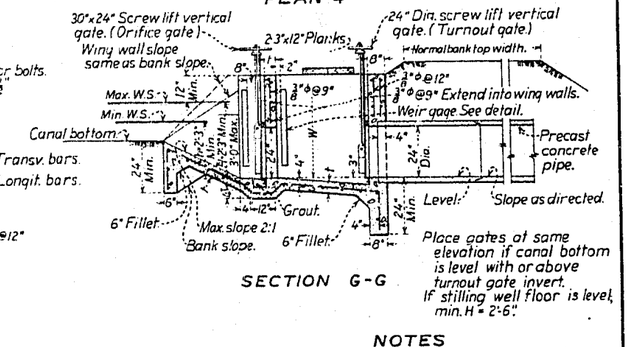


PLAN 4

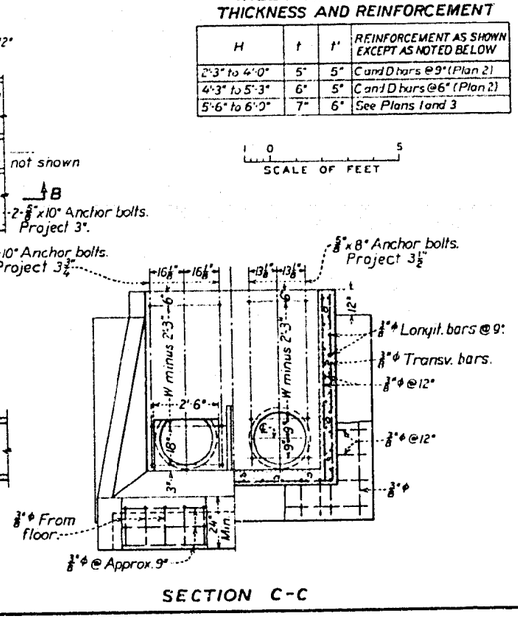


SECTION G-G

INLET WALLS AND FLOOR THICKNESS AND REINFORCEMENT

H	t	t'	REINFORCEMENT AS SHOWN EXCEPT AS NOTED BELOW
2'-3" to 4'-0"	5"	5"	C and D bars @ 9" (Plan 2)
4'-3" to 5'-3"	6"	5"	C and D bars @ 6" (Plan 2)
5'-6" to 6'-0"	7"	6"	See Plans 1 and 3

SCALE OF FEET 0 5



DETAILS OF GAGE

DETAIL NAILING CONCRETE ANCHORS

SECTION C-C

GAGE SETTING

(VERTICAL DIMENSIONS)

H	NOMINAL GAGE LENGTH	HEIGHT OF ZERO OF GAGE ABOVE ORIFICE GATE SILL
* a+10" or 3"	* a	6"
* a+16" or 9"	* a+11"	0"

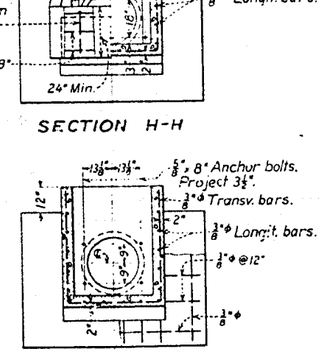
* a = 2'-3" ..... 6' as required.

OPERATION OF ORIFICE GATE

With loss of 0.20' of head

QUANTITY SEC. FT.	APPROX. ORIFICE GATE OPENING
3	0.48
4	0.64
5	0.79
6	0.95
7	1.10
8	1.26
9	1.41
10	1.56

For any desired Q set orifice gate at opening shown (or as determined by calibration) and adjust turnout gate to obtain a difference of 0.20 ft. in the gage readings.
Discharge shown is for one gate only.
Use both gates on 2-bay structure.



SECTION H-H

SECTION J-J

NOTES

All reinforcement shall be placed so that the centers of bars in the outer layer will be 2" from face of concrete unless otherwise shown.
Lap all bars 34 diameters at splices.
Provide head in addition to that required for operation of orifice gate to cover losses through turnout gate and pipe. Where sufficient head is available turnout pipe and gate may be made smaller as directed.
Zero point of both gages to be set at same elevation.
Establish W in 3" increments begining at 3'-3".
Plans 1 and 2 may be adapted to single barrel structures and Plans 3 and 4 to double barrel structures within limits of operating head requirements.
For outlet transitions and collars use Dwgs. 40-D-564 and 40-D-565 with modified pipe spacing.
t = thickness of walls, floor and crosswall of inlet.
t' = thickness of apron of alternate inlet design.
H = head on orifice gate sill. Max. 6'-0" Min. 2'-3".
H' = head on turnout gate sill, no flow, = H or H minus 3".
h = min. head on orifice gate sill measured from min. water surface assumed in canal for full delivery to lateral.
For H of 3'-0" or less use orifice gate Dwg. 40-D-3731 and turnout gate Dwg. 40-D-3705.
For H of 3'-3" to 6'-0" use orifice gate Dwg. 40-D-3702 and turnout gate Dwg. 40-D-3700.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
DENVER OFFICE

CONSTANT HEAD ORIFICE TURNOUT

MAX. CAPACITY 20 SECOND FEET

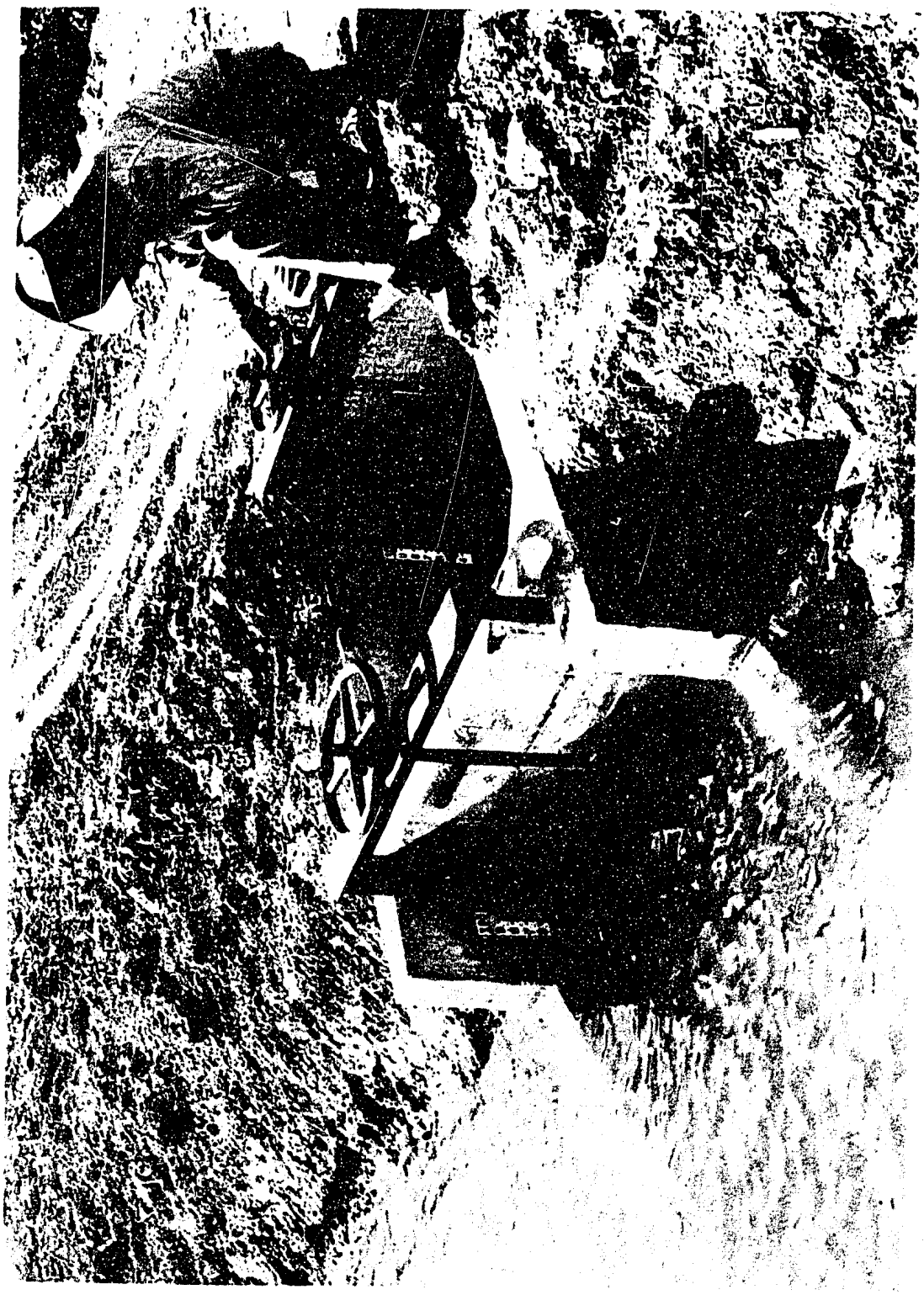
REV. MAY 11, 1945 | 12-26-45 | 1-15-47

DRAWN: D.G.T. I.B.N. SUBMITTED:
TRACED: G.E.W. RECOMMENDED:
CHECKED: A.E.B. APPROVED:

DENVER, COLORADO, MAR. 24, 1941.

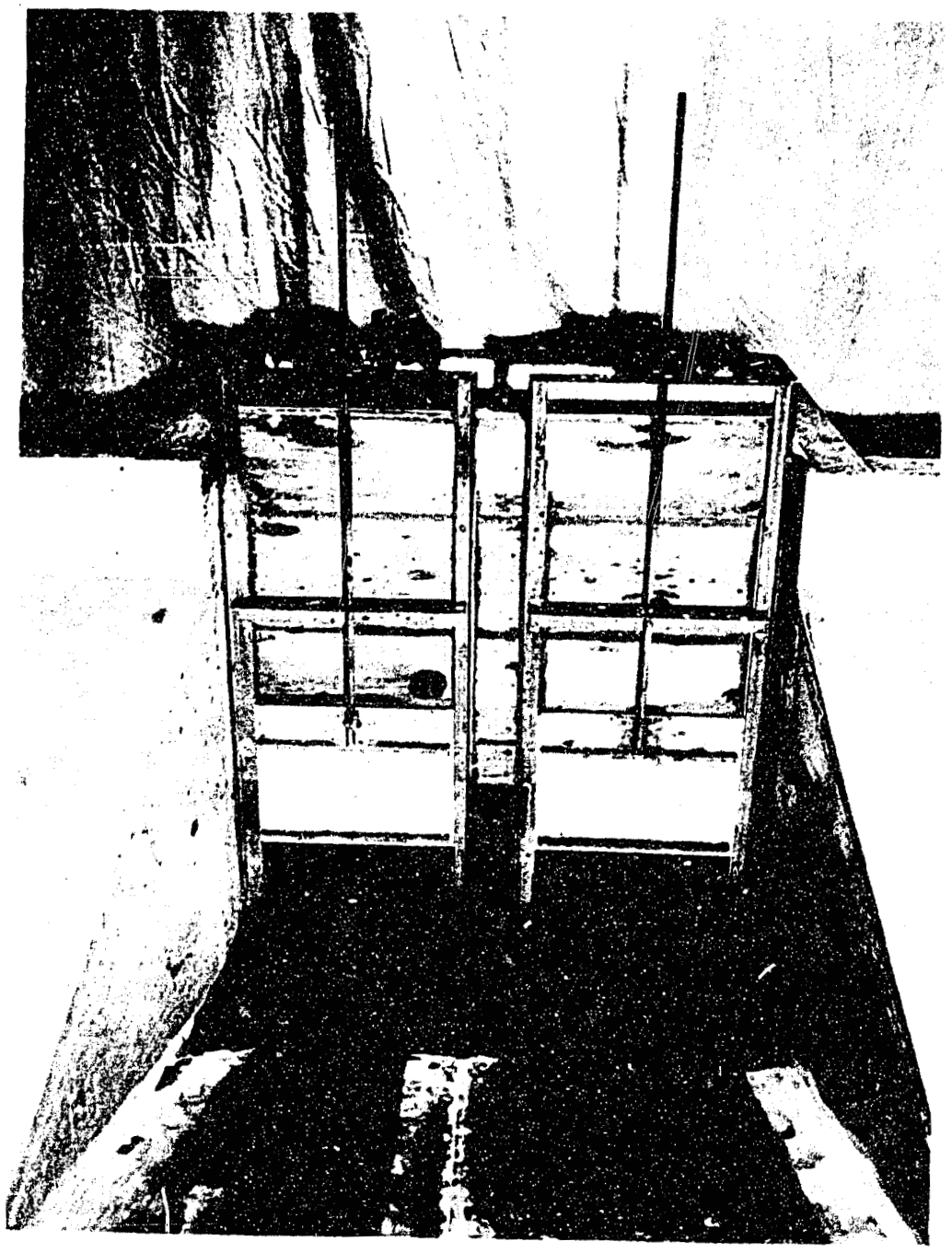
40-D-3673

Figure 3



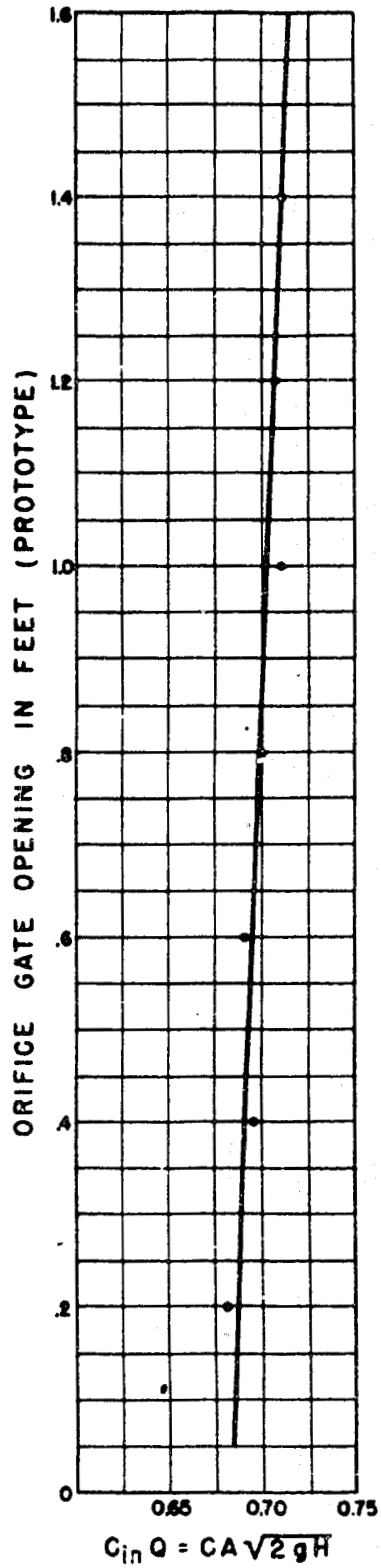
Constant Head Orifice Turnout, Single Barrel Type
Location: Tucumcari Project in New Mexico
A constant head of 0.2 feet is being maintained

Figure 4



Constant Head Orifice Turnout - 1 to 2 Scale Model
Maximum Capacity (Prototype) - 20 Second Feet
Plan 3 - Double Barrel Type

FIGURE 5



NOTE:
Each point represents the average value of C for all runs at that gate opening. A differential head of 0.1 foot model (0.2 foot prototype) was maintained.

CONSTANT HEAD ORIFICE
TURNOUT
COEFFICIENT CURVE
MODEL SCALE 1:2