PAP-722

Evaluation of Potential Ultrasonic Flowmeter Applications at Helena Valley Pumping Plant, Canyon Ferry Dam, Yellowtail Dam, and Tiber Dam

Prepared for the Bureau of Reclamation's Montana Area Office

March 25, 1996

By

Tracy Vermeyen, P.E.
Research Hydraulic Engineer
Water Resources Research Laboratory
Denver, Colorado

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Transit-Time Ultrasonic Flowmeters. - Transit-time ultrasonic (acoustic) flowmeters are based on the principle that transit time of an acoustic signal along a known path is altered by the fluid velocity. An acoustic signal sent upstream travels slower than a signal sent downstream. By accurately measuring the transit times of signals sent in both directions along a diagonal path, the average velocity along the acoustic path can be calculated. Then knowing the path angle with respect to the direction of flow the average axial velocity can be computed (fig. 1a).

An ultrasonic flowmeter is a nonmechanical, nonintrusive device which is capable of measuring discharge in open channels or in pipes. These flowmeters can provide continuous and reliable records of flow rates over a wide range of conditions, including flow in both directions. Some typical applications include:

- Acceptance testing of hydraulic machinery (turbines and pumps)
- Flow measurement in conduits large (360") and small (1/2") diameter
- Hydroelectric powerplant management
- Volumetric metering
- Wastewater or water treatment plants
- Field calibration of other flow measurement devices

The following advantages and disadvantages have been identified for ultrasonic flow measurement:

Advantages

- High accuracy which can be achieved independent of velocity profile, flow rate, and liquid temperature
- Capable of bi-directional flow measurement
- Non-intrusive, therefore there is no head loss
- Field calibrations are generally not required
- System cost is almost independent of pipe size
- No moving parts and are very serviceable

Disadvantages

- Relatively high initial cost
- Requires electronic technician to troubleshoot and service
- Entrained gases and/or suspended sediment affect the acoustic signal

There are two common methods for calculating discharge using ultrasonic flowmeters:

1) **Single-path flowmeter** - One or more pairs of acoustic transducers are mounted diametrically opposed in the measurement section (fig. 1a). An average axial velocity is measured, and along with the known cross sectional area of the conduit, a volumetric flow rate is computed. This technique is based on an assumption that the velocity profile shape in the measurement section is very similar to a fully-developed, turbulent velocity profile. As a result, flowmeter accuracy is

dependent on how well the actual velocity profile compares to the assumed profile. A poor velocity profile will result in flow measurement errors. The typical accuracy for this type of flowmeter is ±3 to 5 percent of the true discharge. However, with good flow conditions and an on-site calibration these meters can be accurate to ±1 percent.

2) **Multi-path flowmeter** - This type of flowmeter uses up to four acoustic paths which are mounted on chordal paths across the measurement section (fig. 1b). The average axial velocity for each path is used to establish the velocity profile. The velocity profile is then numerically integrated over the conduit's cross sectional area to determine the volumetric flow rate. As a result, flowmeter accuracy is relatively independent of the velocity profile. Furthermore, this type of flowmeter does not require calibration to reach the manufacturer's specified accuracy (usually between 0.5 to 2 percent of the flow rate). If upstream conditions disrupt the velocity profile an additional four paths (a second acoustic plane) can be installed which cross the first four paths. This cross path configuration will correct for any non-axial flow components in the acoustic measurement section. Non-axial flow components are usually caused by an upstream valve or bend.

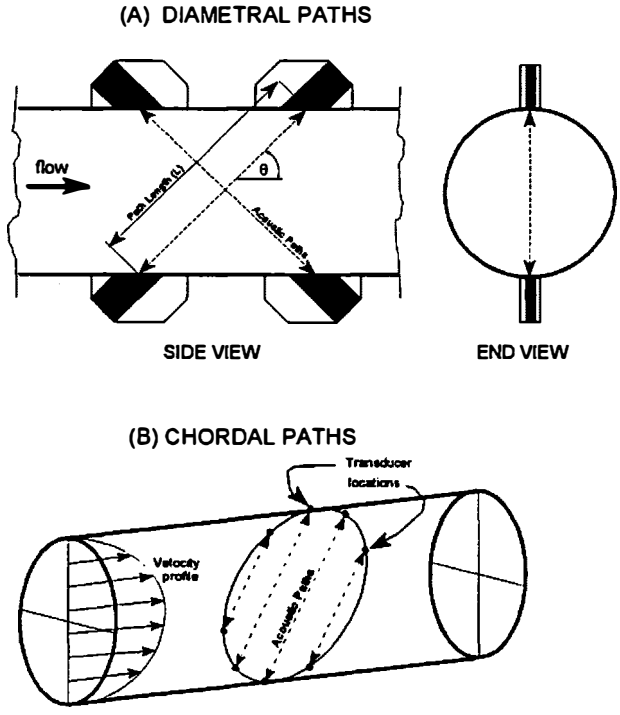


Figure 1. Transit-time ultrasonic flowmeters. (a) Diametral path and (b) a chordal-path transducer configuration.

Standards

ASME Performance Test Code 18 (PTC-18-92)

This code defines procedures for the field performance testing of hydraulic turbines and pump/turbines operating in a turbine mode. It defines accepted methods for ascertaining turbine performance by measuring flow rate, head, and power output to calculate turbine power output and efficiency. This code is recommended for use in conducting turbine acceptance testing as is usually required in Bureau of Reclamation specifications for new or uprated turbines.

ANSI/ASME MFC-5M-1985, Measurement of Liquid Flow in Closed Conduits Using Transit-Time Ultrasonic Flowmeters.

This standard applies only to ultrasonic flowmeters that base their operation on transit-time measurements of acoustic pulses. Furthermore, this standard covers the application of ultrasonic flowmeters used to measure the volumetric flow rate of a liquid of uniform acoustic properties and flowing in a completely filled closed conduit. The standard provides:

- a description of the operating principles employed by the ultrasonic flowmeters
- a description of error sources and performance verification procedures
- a common set of terminology, symbols, definitions, and specifications

PTC-18 is the more stringent of the two standards and should only be used for turbine acceptance testing or applications where flow measurement accuracy is critical, usually for accuracies between 0.5 and 1.0 percent of the true discharge.. **ANSI/ASME MFC-5M-1985** is the more general standard which should be used for selection and installation of ultrasonic flowmeters when accuracies of 1 to 10 percent are required.

Reclamation Practices

For turbine acceptance testing Reclamation usually tests one turbine in accordance with PTC-18, unless otherwise noted in the specifications. As a result, eight-path ultrasonic flowmeters are installed on the penstock being tested. However, the level of flow measurement accuracy required for project operations can also influence the type of flowmeters installed. For example, all the penstocks at Hoover, Parker, and Davis Dams are equipped with ultrasonic flowmeters because accuracies of ±1 percent are required by the Lower Colorado River water accounting decree. Another consideration is that the Denver Technical Service Center's Hydraulic Equipment Group (D-8420) is equipped with portable ultrasonic flowmeters which can be installed for turbine acceptance testing on a temporary basis.

Ultrasonic flowmeter Installation Guidelines for Helena Valley Pumping Plant, Montana - 10-ft diameter penstock

For the 10-ft diameter penstock to the pump-turbine (pipe from Canyon Ferry Dam to pumping plant) the following ultrasonic flowmeter installation recommendations are made in accordance to ASME's PTC 18-1992.

- The flowmeter installation location should be between stations 3+29 and 3+60 (see attached drawing 596-D-82). This location assure at least 10 pipe diameters of straight pipe upstream of the site and 3 pipe diameters of straight pipe downstream from bends at stations 2+29 and 4+10, respectively. Note: this location assumes that the there is not a need to accurately measure flow back to Canyon Ferry Lake. If this is not the case, you should provide 10 pipe diameters of straight pipe on either side of the flowmeter installation location.

- For a 45° path angle the installation will require ±10 linear ft of penstock.

- To satisfy ASME's PTC-18 for hydraulic turbine acceptance testing, an 8-path Ultrasonic flowmeter installation should be installed at this location. However, if your accuracy requirements do not require accuracies of ±0.5% of the actual discharge you can use a 4-path system and attain accuracies in the ±1.0% range. Or a 2 or 3 path system for accuracies in the 2 to 3% range.

- If you decide on an 8-path system, the acoustic paths are normally installed in an horizontal plane. However, PTC-18 requires them to be installed so that the intersection of the two acoustic planes be in the same plane as the nearest upstream bend. In this case the combined bend at Sta 2+29 and if my interpretation of the drawing is correct the plane of the bend is 6° 27' 35". As a result, the acoustic paths should be rotated 6° 27' 35" clockwise from the horizontal plane when looking in the downstream direction. If a 4-path system is used, I would recommend mounting the transducers at an angle of 6° 27' 35" clockwise from horizontal.

- From Accusonics price quotes dated 3/19/96 an 8-path system at this site would cost $32, 500 (this includes a Model 7520 flow transmitter not included on the price quote, but I confirmed this cost in a telephone contact) and a 4-path system would cost $17,200. Note that this is for equipment only and does not include installation expenses which is usually $5,000 to 7,000.

For a system with an accuracy in the 2 to 5 percent range I would recommend a two to three path ultrasonic flowmeter with wet mounted transducers. This type of installation should follow the **ANSI/ASME MFC-5M-1985** standard.

- Although I did not receive a quote from Accusonics, I calculated the cost of a two or three-path system to be about $12,000 and $14, 000, respectively. I would not recommend a one-path system because of the limited accuracy and there is no redundancy in the transducers. That is if one transducer fails you lose the ability to measure the flow in that penstock.

Ultrasonic flowmeter Installation Guidelines for Helena Valley Pumping Plant, Montana - 75-inch Diameter Steel Discharge Pipeline

For the 75-inch diameter steel discharge pipeline which carries water from the pump-turbine to the Helena Valley Irrigation District, the following ultrasonic flowmeter installation recommendations are made in accordance to ASME's PTC 18-1992.

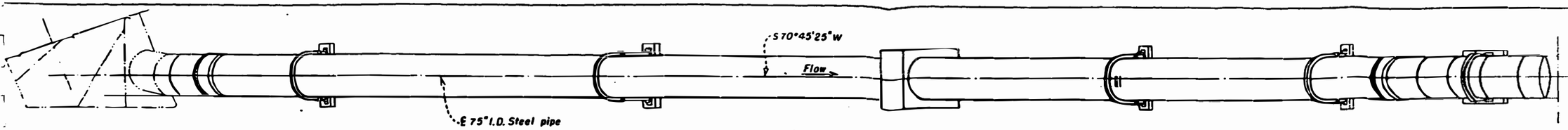
- Installation location should be past Station 1+78 (see attached drawing 596-D-84). This location assure at least 10 pipe diameters of straight pipe upstream of the site from the bend at Station 0+92.57. Because there are no significant obstructions beyond station 1+78 until Station 3+00 the ultrasonic flowmeter can be located anywhere between those two stations. However, because of the complexity of the pump discharge lines and combined bend at station 0+92.57 I would recommend a location with at least 10 to 20 diameters of straight pipe upstream.

- For a 45° path angle the installation will require ±6.25 linear ft of penstock.

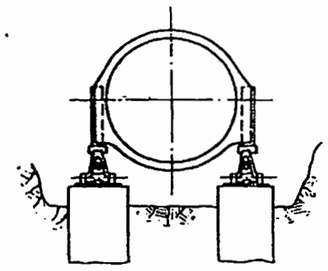
- To satisfy ASME's PTC-18 for hydraulic turbine acceptance testing, an 8-path ultrasonic flowmeter installation would be required at this location. However, if your accuracy requirements do not require accuracies to within ±0.5% of the actual discharge you can use a 4-path system and attain accuracies in the ±1.0% range. Or a 2 or 3 path system for accuracies in the 2 to 3% range.

- PTC-18 requires 8-path ultrasonic systems be installed so that the intersection of the two acoustic planes be in the same plane as the nearest upstream bend. In this case the combined bend at Sta 0+92, and if my interpretation of the drawing (596-D-84) is correct the plane of the bend is 75° 32' 24". As a result, the acoustic paths should be rotated 75° 32' 24"counterclockwise from the horizontal plane when looking in the downstream (uphill) direction. If a 4-path system is used I would recommend mounting the transducers at a location with at least 20 diameters of straight pipe upstream.

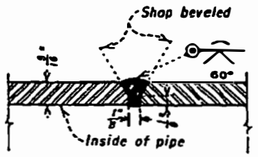
- From Accusonics price quotes dated 3/19/96 an 8-path system at this site would cost $30,500 (this includes a Model 7520 flow transmitter not included on the price quote, but I confirmed this cost with Accusonics) and a 4-path system would cost $17,200. Note that this is for equipment only and does not include installation expenses. For a system with an accuracy in the 2 to 5 percent range I would recommend a two to three path ultrasonic flowmeter with wet mounted transducers. This type of installation should follow the **ANSI/ASME MFC-5M-1985** standard. Although I did not receive a quote from Accusonics, I calculated the cost of a two or three-path system to be about $12,000 and $14, 000, respectively.



PLAN

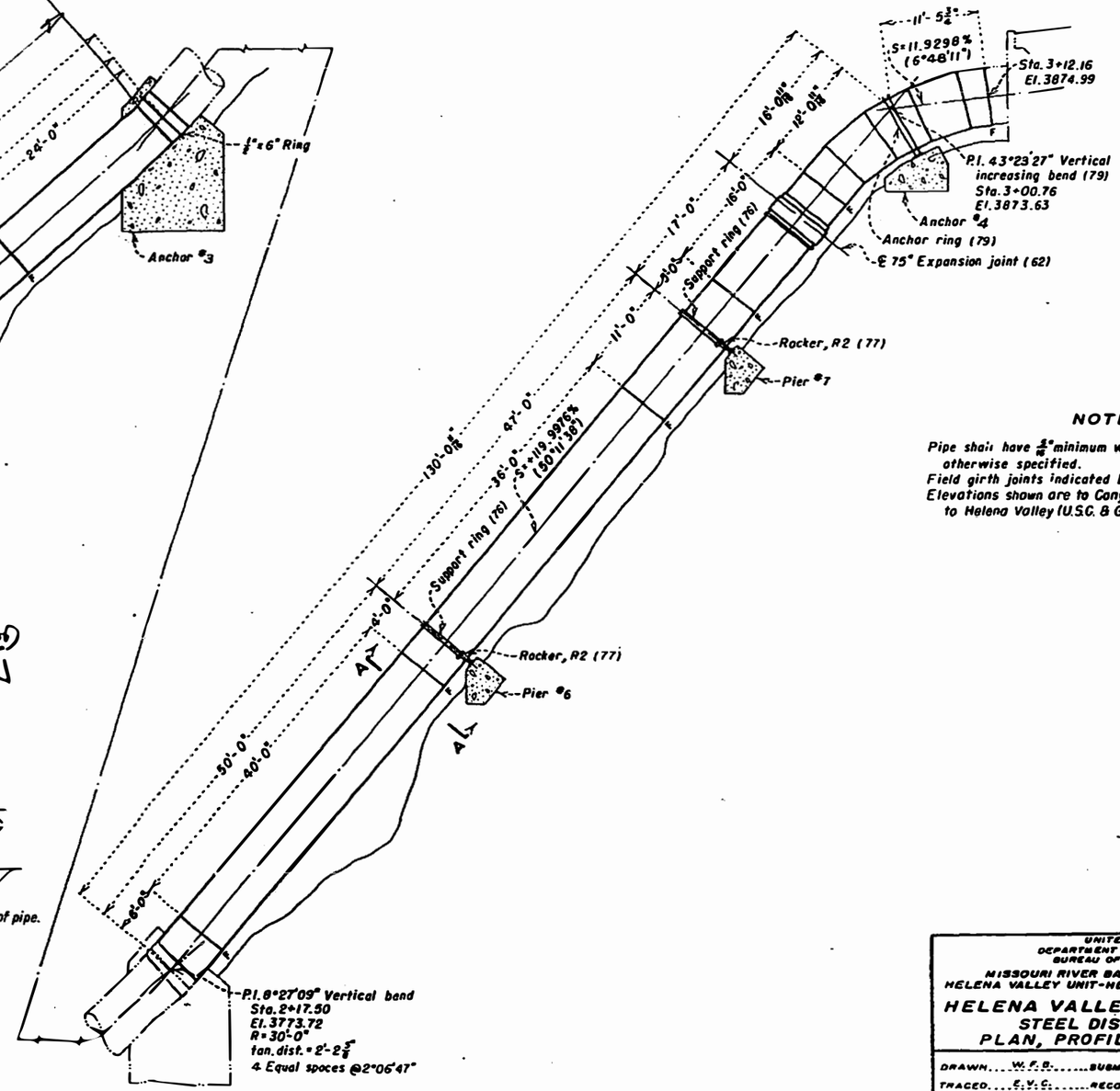


SECTION A-A



FIELD GIRTH JOINT

DETAIL 1



PROFILE

NOTES

Pipe shall have 5/16" minimum wall thickness unless otherwise specified.
Field girth joints indicated by the letter F.
Elevations shown are to Canyon Ferry datum. To convert to Helena Valley (U.S.C. & G.S.) datum add 0.21 feet.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT-MONTANA
HELENA VALLEY UNIT-HELENA-GREAT FALLS DIVISION

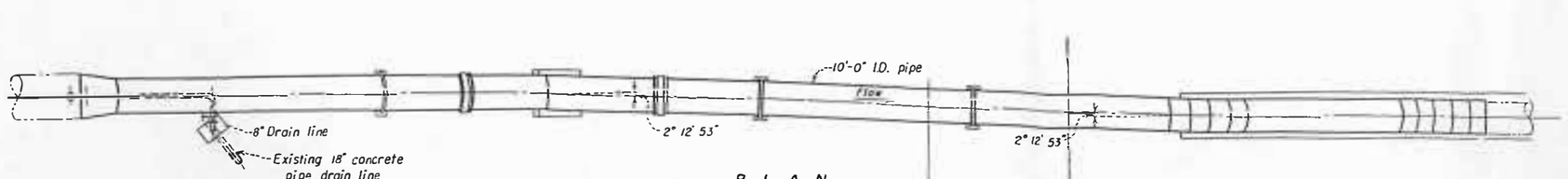
HELENA VALLEY PUMPING PLANT
STEEL DISCHARGE PIPE
PLAN, PROFILE AND DETAILS

DRAWN W.F.B. SUBMITTED F. Heidinger
TRACED E.V.C. RECOMMENDED
CHECKED J.J.W. APPROVED Chief, Mechanical Branch
DENVER, COLORADO, AUG. 12, 1955

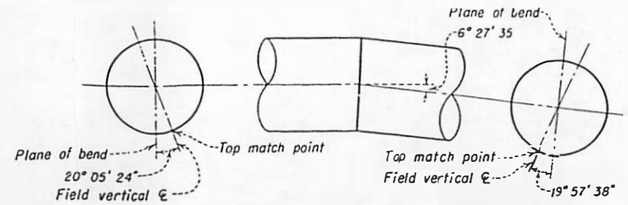
596-D-84

596-D-84

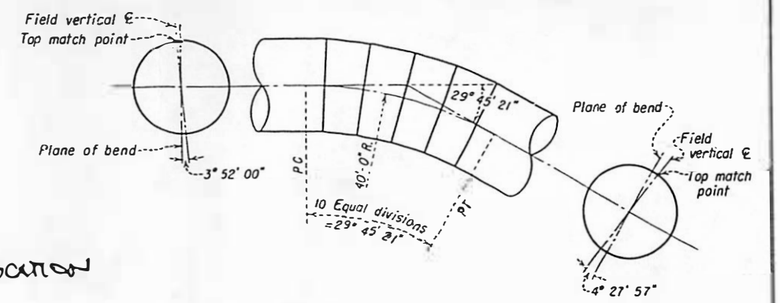
NOVEMBER 26, 1973



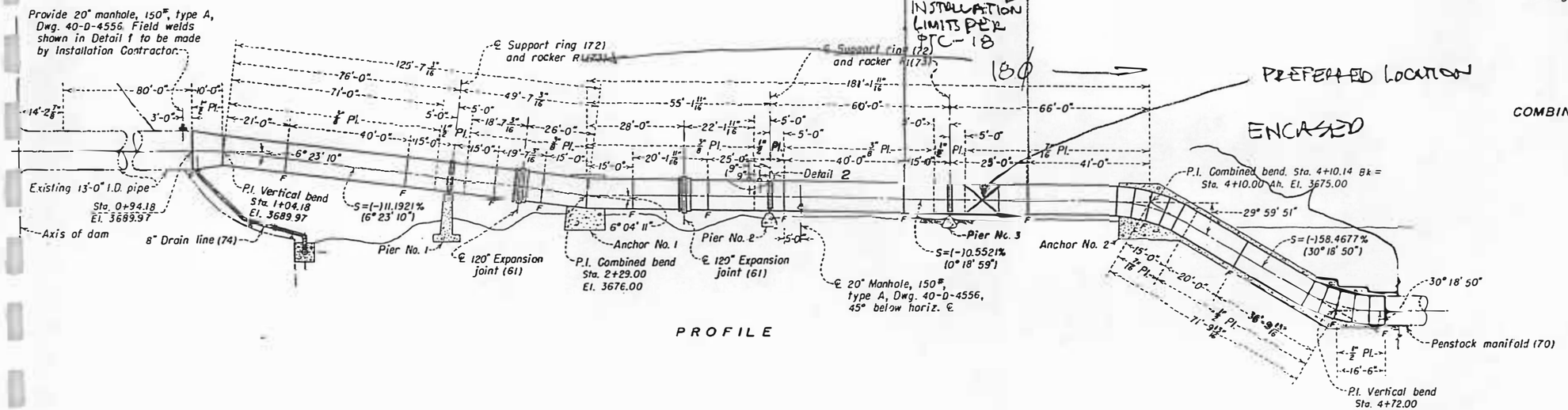
PLAN



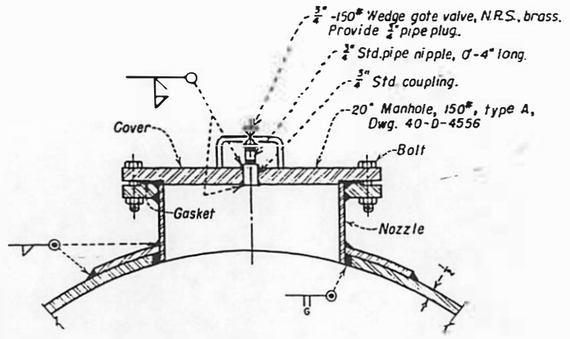
COMBINED BEND—STA. 2+29.00



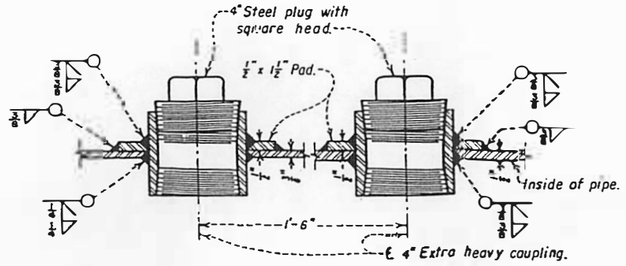
COMBINED BEND—STA. 4+10.14 BK. = STA. 4+10.00 AH.



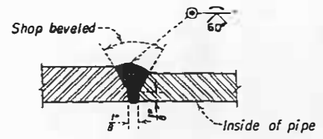
PROFILE



DETAIL 1



DETAIL 2



FIELD GIRTH JOINT

NOTES

Welded field girth joints indicated by the letter "F".
Elevations shown are to Canyon Ferry datum.
To convert to Helena Valley (U.S.C. & G.S.) datum add 0.21 feet.

1-14-57 D JJW	REVISED INTERMEDIATE DIMENSIONS TO AGREE WITH OVERALL DIMENSIONS.

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MISSOURI RIVER BASIN PROJECT - MONTANA
HELENA VALLEY UNIT - HELENA - GREAT FALLS DIVISION

HELENA VALLEY PUMPING PLANT
STEEL PENSTOCK
PLAN, PROFILE AND DETAILS

DRAWN W.F.G. SUBMITTED F. Heidinger
TRACED F.F.M. RECOMMENDED
CHECKED J.J.W. APPROVED
CHIEF, MECHANICAL BRANCH

DENVER, COLORADO, AUGUST 12, 1955

596-D-82

6-596-03-01-01

Ultrasonic flowmeter Installation Guidelines for Canyon Ferry Power Penstocks, Montana

For the three 13.5 ft diameter penstocks at Canyon Ferry Dam the following ultrasonic flowmeter installation recommendations are made in accordance to ASME's PTC 18-1992.

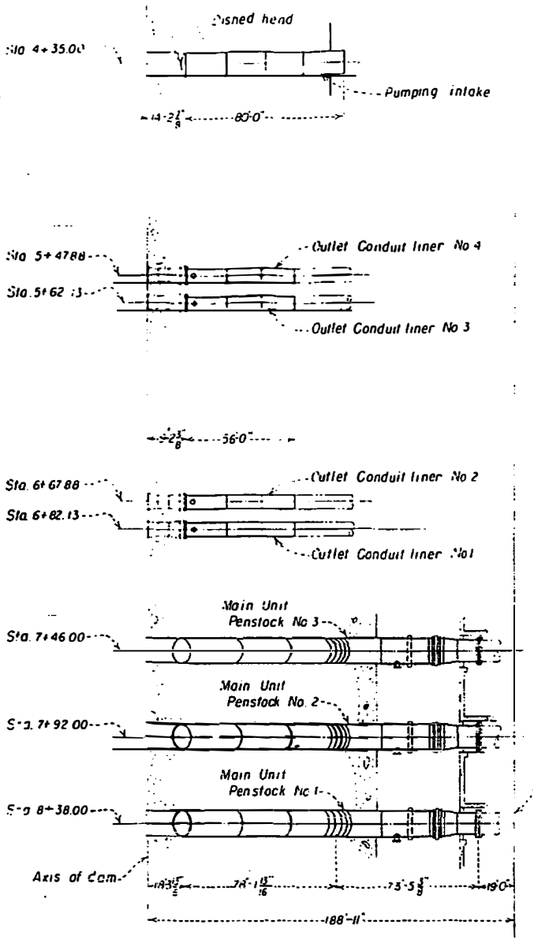
- For externally mounted transducers, the recommended installation location is in the 25-ft-long room containing the manhole. Preferably, the transducers should be installed upstream of the expansion joint and downstream of the manhole (see attached drawing 296-D-188). This recommendation is valid for all three penstocks. This location does not provide 10 pipe diameters of straight pipe upstream of the ultrasonic flowmeter measurement section nor 3 pipe diameters of straight pipe downstream.

- For a 45° path angle the installation will require ±13.5 linear ft of penstock.

- To satisfy ASME's PTC-18 for hydraulic turbine acceptance testing, an 8-path ultrasonic flowmeter installation should be installed on at least one of these three penstocks and could be installed at a later date. Because of the similarity between the penstock designs either of the three penstocks can be used.

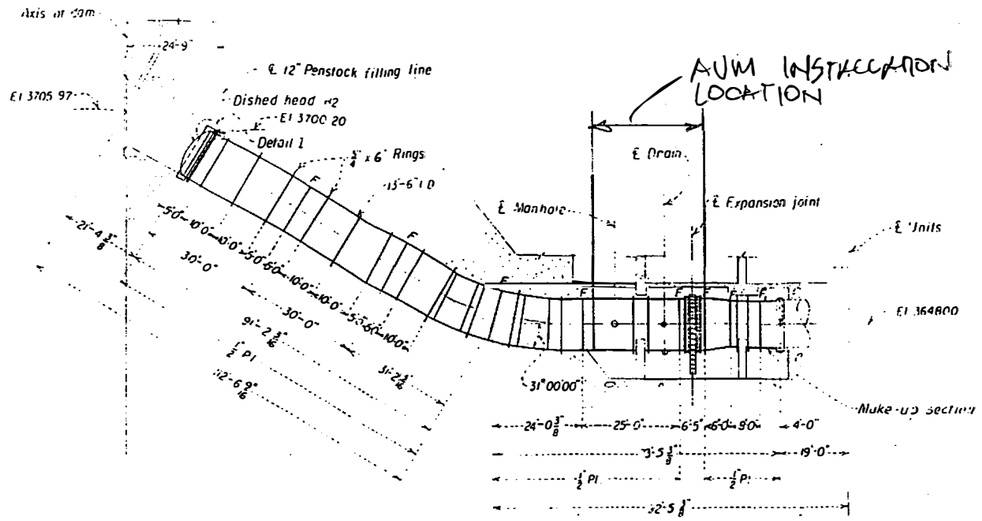
- PTC-18 requires that an 8-path ultrasonic systems be installed so that the intersection of the two acoustic planes be in the same plane as the nearest upstream bend. In this case the 31° vertical bend, located 24 ft upstream (drawing 296-D-188), would require the installation of horizontal acoustic paths. Care must be taken to avoid interference with the manhole, expansion joint, and drain line.

- From Accusonics price quotes dated 3/19/96 an 8-path system for all three penstocks at Canyon Ferry Dam would cost $86,500 (this includes a Model 7520 flow transmitter not included on the price quote, but I confirmed this cost in a telephone call to Accusonics). A 4-path system on three penstocks would cost $51,300. Note that this is for equipment only and does not include installation expenses. Another alternative would be to install one 8-path system to meet PTC-18 for future acceptance tests and two 4-path systems on the other two penstocks for a cost of $60,700.

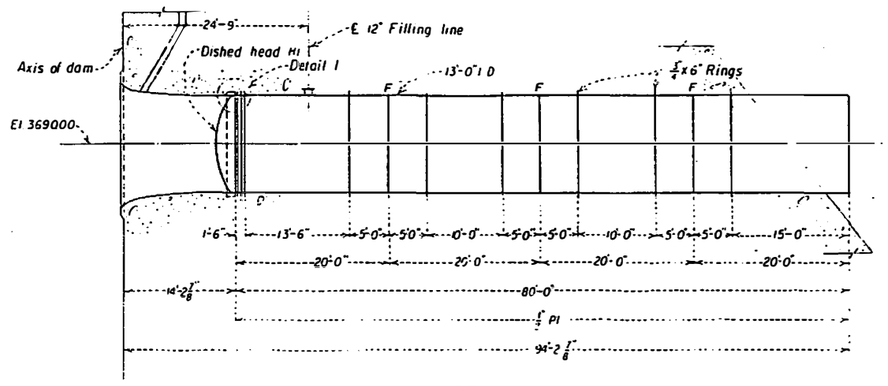


PLAN

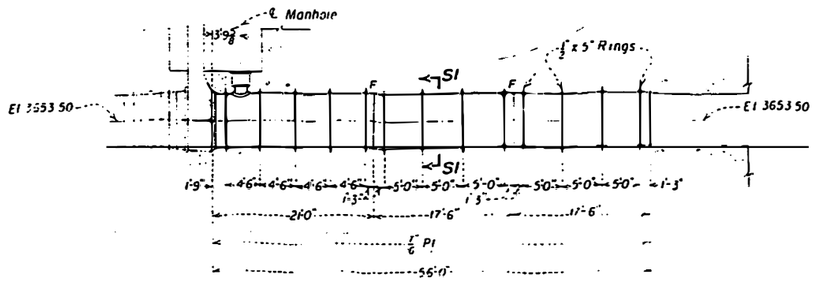
RINGS NOT SHOWN



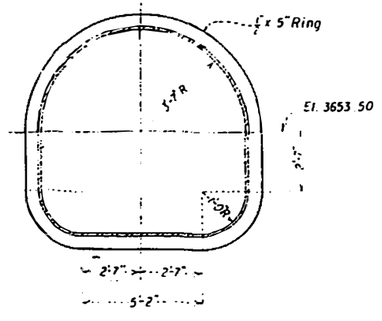
PROFILE
MAIN UNIT PENSTOCKS



PROFILE
PUMPING INTAKE

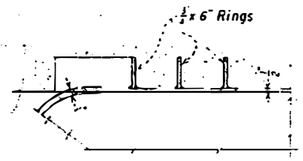


PROFILE
OUTLET CONDUIT LINERS



SECTION SI-SI

FIELD GIRTH JOINT



DETAIL 1

NOTES

The location of field girth joints are indicated by the le
The F₁ joint to be welded by the turbine installation contracto

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CANYON FERRY UNIT - MONTANA

CANYON FERRY DAM
PENSTOCKS-PUMPING INTAKE-OUTLET CONDUI
PLAN AND PROFILES

DRAWN F.B. SUBMITTED
TRACED A.R.L. RECOMMENDED
CHECKED APPROVED

DENVER COLORADO, MAY 6, 1948

296

296-D-188

CORRECTED 5-21-48 A.R.L.

Ultrasonic flowmeter Installation Guidelines for Yellowtail Dam Power Penstocks, Montana

For the four 12.0 ft diameter penstocks (reduced to 9.25 ft at turbine) at Yellowtail Dam the following ultrasonic flowmeter installation recommendations are made in accordance to ASME's PTC 18-1992.

- For externally mounted transducers, the recommended installation location is in Room 204 (see attached drawings 459-D-285 and 534). Preferably, the transducers should be installed between the two sleeve-type couplings. This recommendation is valid for all four penstocks. This location does not provide 10 pipe diameters of straight pipe upstream of the ultrasonic flowmeter measurement section nor 3 pipe diameters of straight pipe downstream. In addition, these proposed ultrasonic flowmeter sites have very poor approach conditions generated by a combined, vertical reducing, and horizontal bends located upstream of the measurement section. Although the vertical reducing bend will likely improve the velocity profile to some degree.

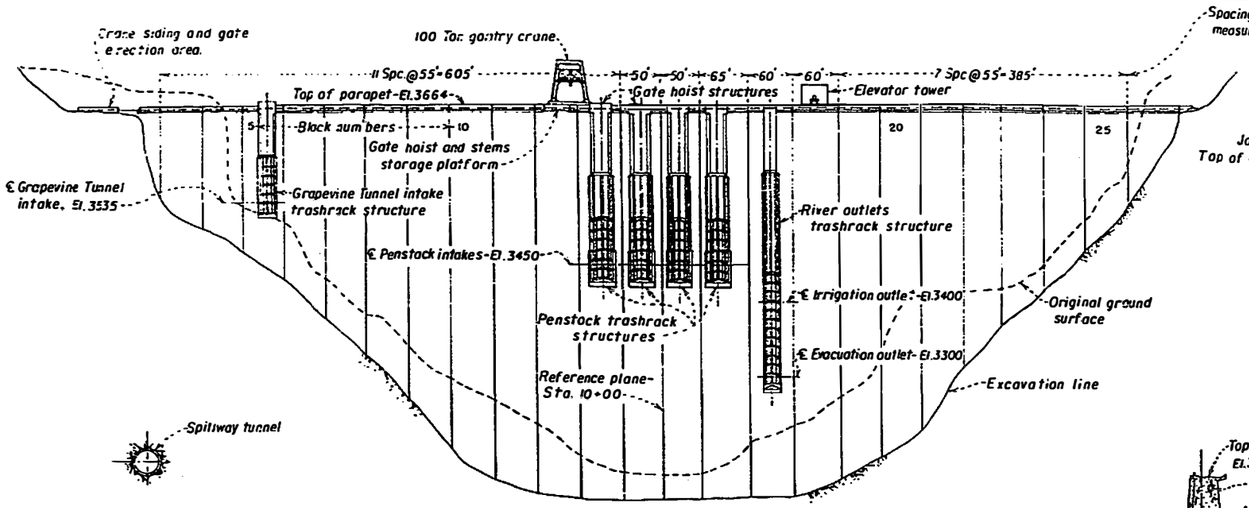
- For a 45° path angle the installation will require ±9.25 linear ft of penstock.

- To satisfy ASME's PTC-18 for hydraulic turbine acceptance testing, an 8-path ultrasonic flowmeter installation would be required for least one of the four penstocks at Yellowtail Dam and could be installed at a later date.

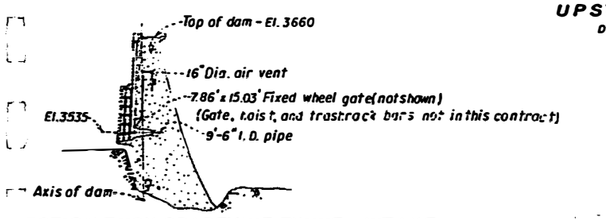
- PTC-18 requires that an 8-path ultrasonic systems be installed so that the intersection of the two acoustic planes be in the same plane as the nearest upstream bend. In this case the horizontal bend, located about 34 ft upstream (drawing 459-D-531& 534), would require the installation of vertical acoustic paths. Care must be taken to avoid interference with the manhole, sleeve-type coupling, and the water supply connection.

- These penstock designs are symmetrical about axis station 10+00, so penstocks 1 and 4 and penstocks 2 and 3 are mirror images of each other. As a result, if economics and accuracy requirements warrant, 8-path systems could be mounted on penstocks 1 and 3 and 4-path systems on penstocks 2 and 4. This would allow for evaluation of cross flow errors using the 8-path systems. If cross flow errors are found using the 8-path systems corrections could be applied to the penstocks with 4-path systems. While this suggestion does not meet PTC-18 requirements it has be done at Parker and Davis Dams, as well as other Reclamation projects.

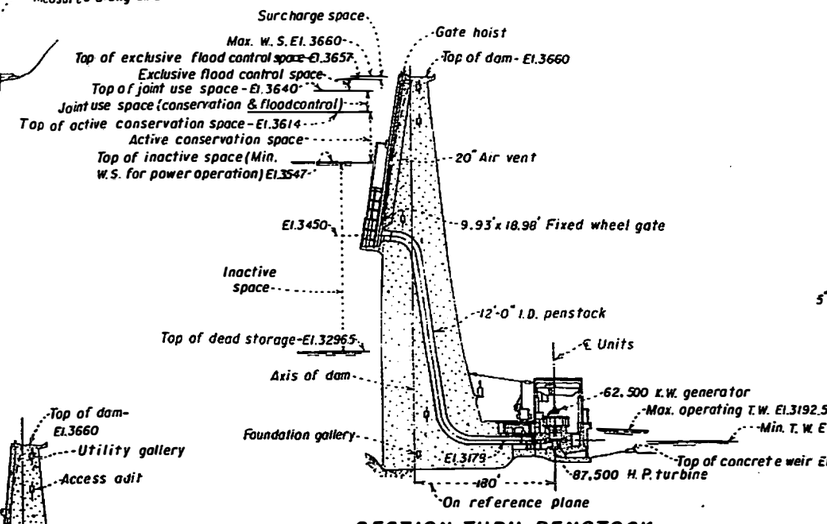
- Using information from Accusonics price quotes dated 3/19/96, an 8-path system for all four penstocks at Yellowtail Dam would cost $112,400 (this includes 3 Model 7520 flow transmitters). Two 8-path and two 4-path systems would cost $86,500. Note that this is for equipment only and does not include installation expenses. A minimum recommended configuration would be four 4-path systems which would cost about $60,700.



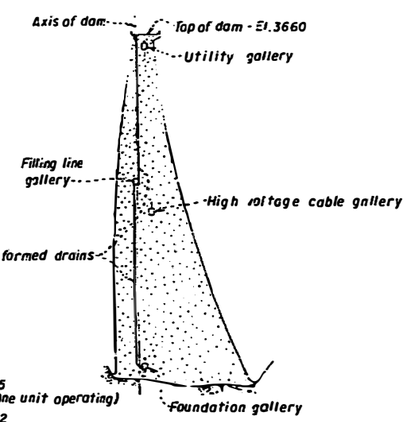
UPSTREAM ELEVATION
DEVELOPED ALONG AXIS



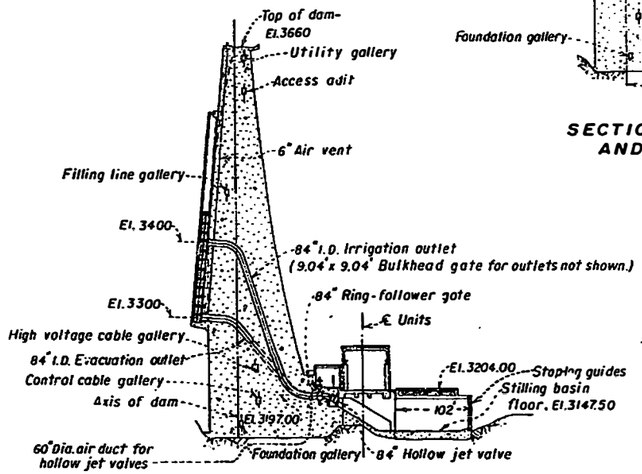
SECTION THRU GRAPEVINE TUNNEL INTAKE



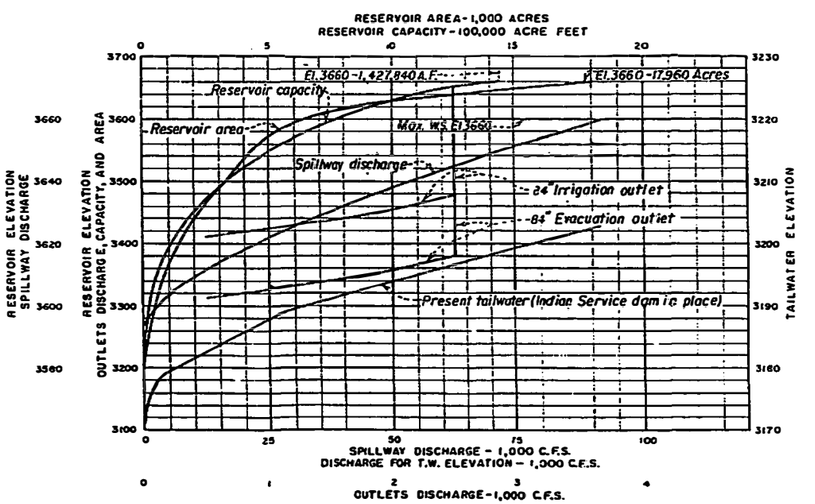
SECTION THRU PENSTOCK AND POWER PLANT



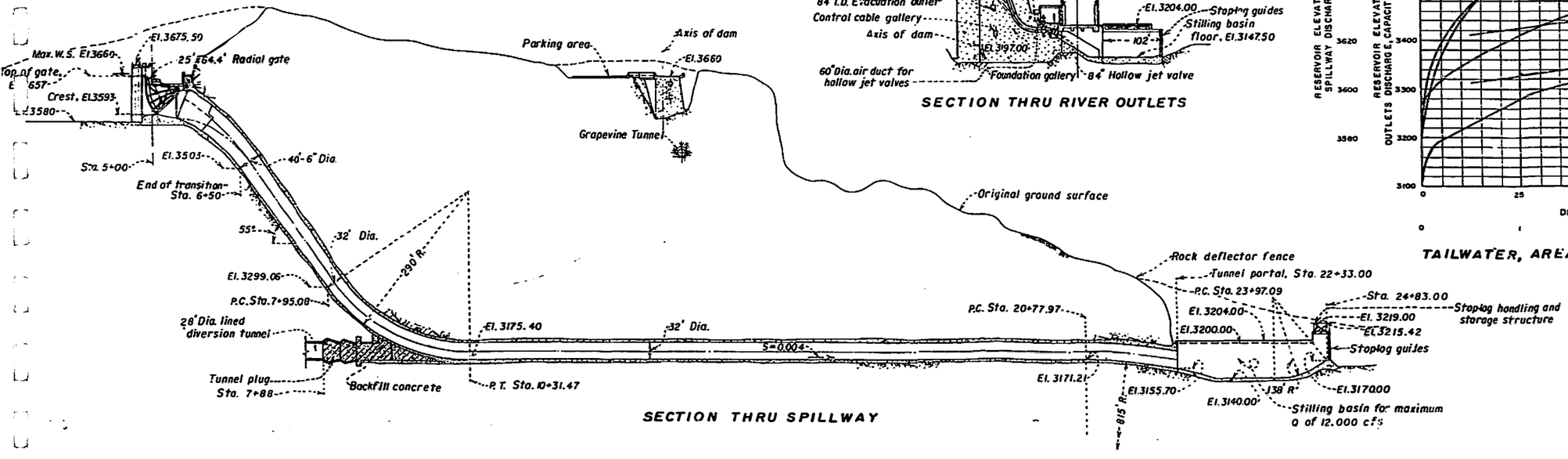
SECTION THRU DAM



SECTION THRU RIVER OUTLETS



TAILWATER, AREA, CAPACITY, AND DISCHARGE CURVES



SECTION THRU SPILLWAY

5-31-63 REVISED TO CONFORM WITH CURRENT CONSTRUCTION D-C.O.S. DRAWINGS. RETRACED

SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-MONTANA

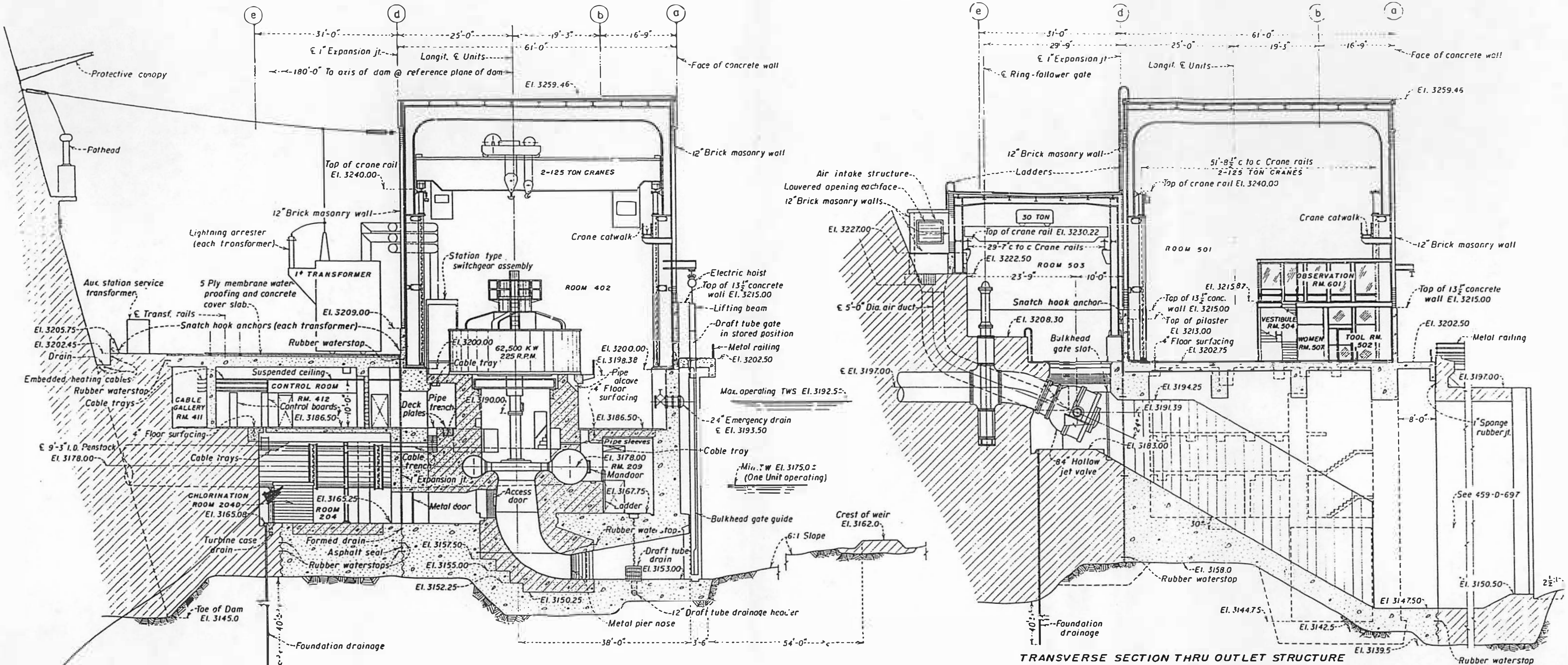
YELLOWTAIL DAM AND POWER PLANT
ELEVATION AND SECTIONS

DRAWN	H.M.C.-A.Q.	SUBMITTED	O. L. Rice
TRACED	C. A. S.	RECOMMENDED	L. G. Puls
CHECKED	F.S.O.-F.S.S.	APPROVED	Grant Bloodgood, ASST. COMM. AND CHIEF ENGINEER

DENVER, COLORADO, JAN. 3, 1961

459-D-230

21" x 36"



TRANSVERSE SECTION THRU ℄ OF UNIT
(UNIT No. 2)

TRANSVERSE SECTION THRU OUTLET STRUCTURE

FLOWMETER INSTALLATION LOCATION.

SCALE OF FEET

NOTE

For general notes, explanation and reference drawings, see 459-D-282.

THIS DRAWING SUPERSEDES DWG. 459-D-

6-30-64 D. R.A.O.	RETRACED. REDUCED SIZE OF GENERATORS. REMOVED METAL ~~PLATFORM. ADDED POTHEAD~~ AND PROTECTIVE CANOPY.
10-10-63 D. R.A.O.	REVISED DRAFT TUBE PASSAGEWAY, RELOCATED BUS, ADDED GENERATOR FOUNDATION AND TOURIST FACILITIES NEAR TOOL RM.
1-28-63 D. R.A.O.	RAISED GENERATOR FLOOR AND METAL PLATFORM. ENLARGED TRANSF. ADDED AUXILIARY STATION SERVICE TRANSF. AND TROLLEY BEAM. OTHER GENERAL REVISIONS.
8-6-62 D. R.A.O.	CHANGED GENERATOR RATING TO 62,500 K.W. CHANGED MIN. T.W. TO EL. 3175.0
4-6-62 D. R.A.O.	REVISED OUTLINE OF DAM, LOWERED FLOOR IN OUTLET STRUCTURE, RAISED DRAFT TUBE GATE DECK CHANGED, CATWALK FROM B. TO D. LINE

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION - YELLOWTAIL UNIT--M

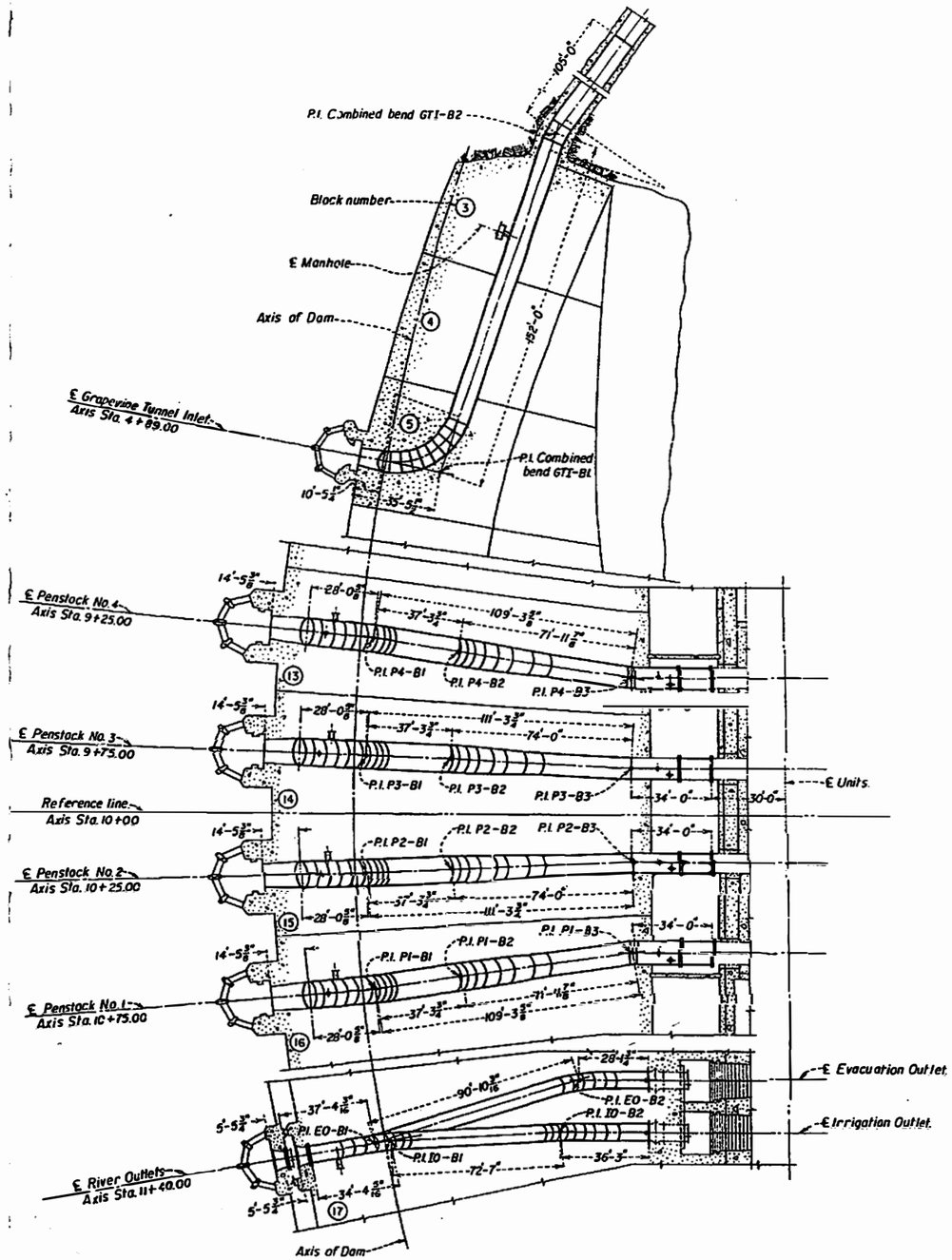
YELLOWTAIL POWER PLA

GENERAL ARRANGEMENT TRANSVERSE SECTIONS ℄ OF UNIT AND OUTLET STRUCT

DRAWN ... SUBMITTED Samuel Judc
TRACED ... RECOMMENDED L.G. Puls
CHECKED ... APPROVED Grant Blood

DENVER, COLORADO. JAN. 25, 1961 | 459-D-

459 — D-285



PLAN

BEND DATA

PENSTOCK NO.	BEND NO.	TYPE OF BEND	Δ	PLAN ANGLE	UPSTREAM PROFILE ANGLE	DOWNSTREAM PROFILE ANGLE	DETAILED ON DWG. NO.
1	P1-B1	Combined	73°18' 46"	3° 02' 07"	8° 41' 56"	82° 00' 00"	459-D-536
1	P1-B2	Vertical reducing	82°00'00"	0°	82°00'00"	0°	459-D-538
1	P1-B3	Horizontal	8° 24' 25"	8° 24' 25"	0°	0°	459-D-538
2	P2-B1	Combined	73°18' 05"	0° 27' 13"	8° 41' 56"	82° 00' 00"	459-D-536
2	P2-B2	Vertical reducing	82°00'00"	0°	82°00'00"	0°	459-D-538
2	P2-B3	Horizontal	2° 14' 39"	2° 14' 39"	0°	0°	459-D-538
3	P3-B1	Combined	73°18' 05"	0° 27' 13"	8° 41' 56"	82° 00' 00"	459-D-537
3	P3-B2	Vertical reducing	82°00'00"	0°	82°00'00"	0°	459-D-538
3	P3-B3	Horizontal	2° 14' 39"	2° 14' 39"	0°	0°	459-D-538
4	P4-B1	Combined	73°18' 46"	3° 02' 07"	8° 41' 56"	82° 00' 00"	459-D-537
4	P4-B2	Vertical reducing	82°00'00"	0°	82°00'00"	0°	459-D-538
4	P4-B3	Horizontal	8° 24' 25"	8° 24' 25"	0°	0°	459-D-538
IRRIGATION CUTLET							
	I0-B1	Combined	64°59'15"	6° 18' 12"	5° 08' 34"	70° 00' 00"	459-D-533
	I0-B2	Combined	70°02'38"	3° 43' 25"	70°00'00"	0°	459-D-533
EVACUATION OUTLET							
	E0-B1	Combined	42°53'39"	7° 52' 32"	5° 08' 34"	47° 30' 00"	459-D-533
	E0-B2	Combined	49°59'35"	17°54' 09"	47°30'00"	0°	459-D-533
GRAPEVINE TUNNEL							
	GT1-B1	Combined	82° 33' 31"	82°03' 52"	2° 51' 45"	0° 18' 54"	459-D-539
	GT1-B2	Combined	16° 43' 59"	16° 44' 00"	0° 18' 54"	0° 18' 54"	459-D-539

LIST OF DRAWINGS

12-28-61 | CORRECTED EXCAVATION OUTLET PLAN ANGLES
D. Nel

THIS DRAWING SUPERSEDES DWG. 459-D-249

UNITED STATES
DEPARTMENT OF THE INTERIOR
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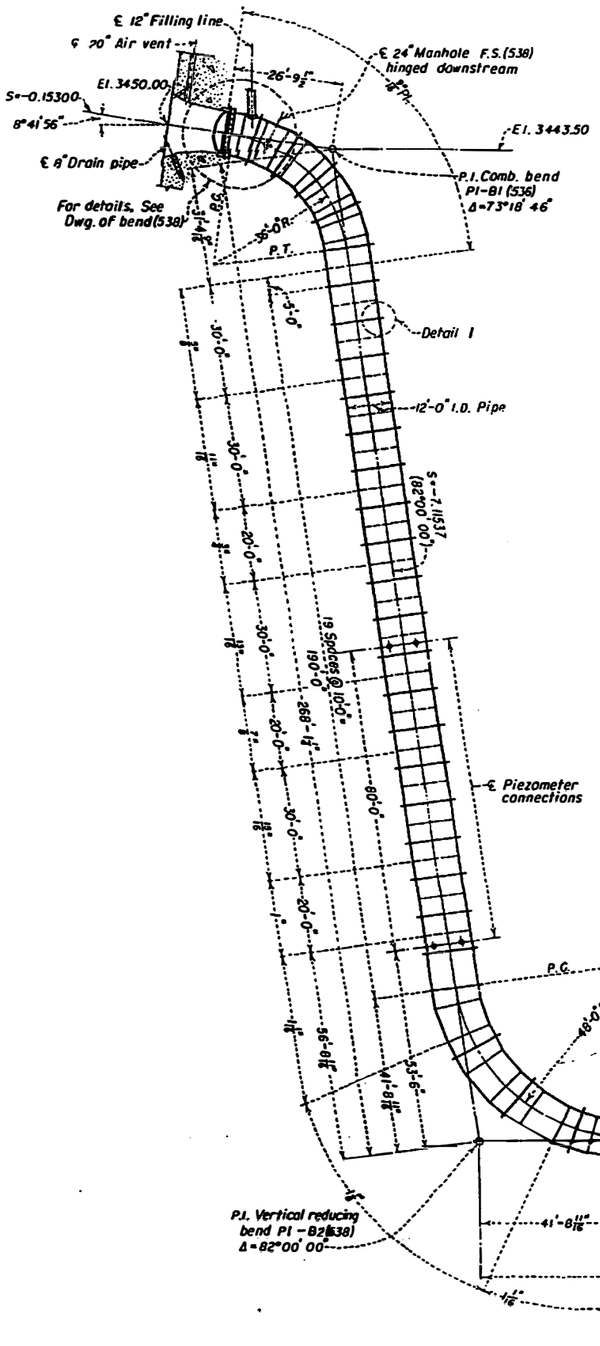
MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-MONTANA

YELLOWTAIL DAM

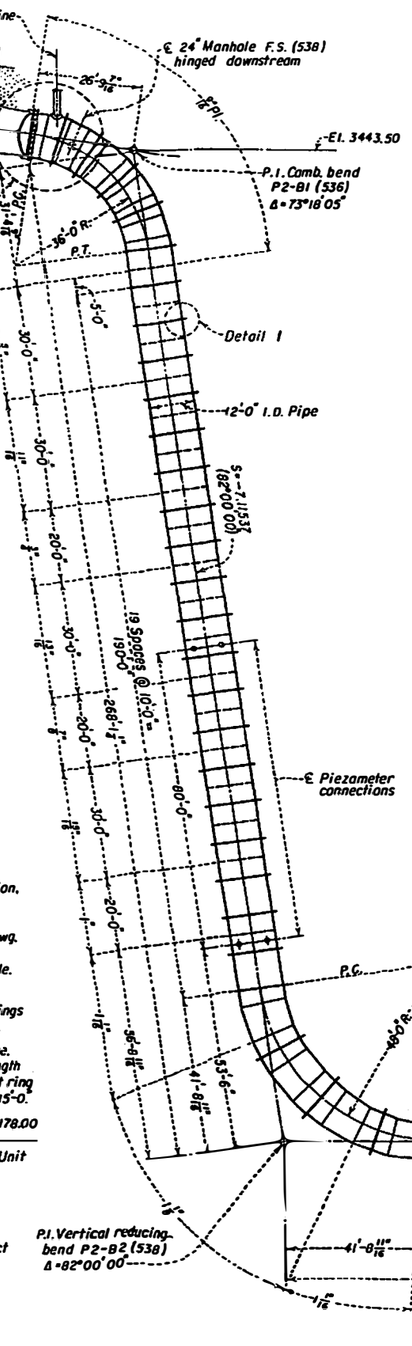
PENSTOCKS AND OUTLET PIPES GENERAL PLAN AND LIST OF DRAWINGS

DRAWN L.M.N. SUBMITTED F. Waldinger
TRACED Y.L.P. RECOMMENDED W.E. Life
CHECKED N.C.P. W.N.I. APPROVED O. Ertl
CHIEF ENGINEERING ENGINEER

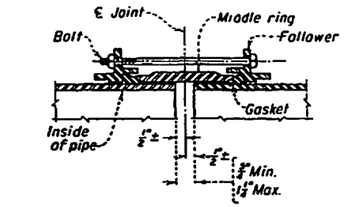
DENVER, COLORADO, NOV. 27, 1961 | 459-D-531



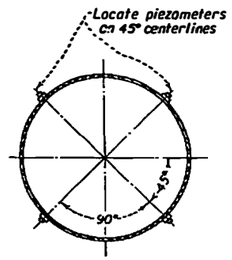
PROFILE PENSTOCK No. 1



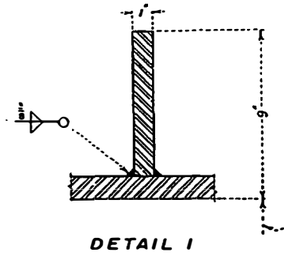
PROFILE PENSTOCK No. 2



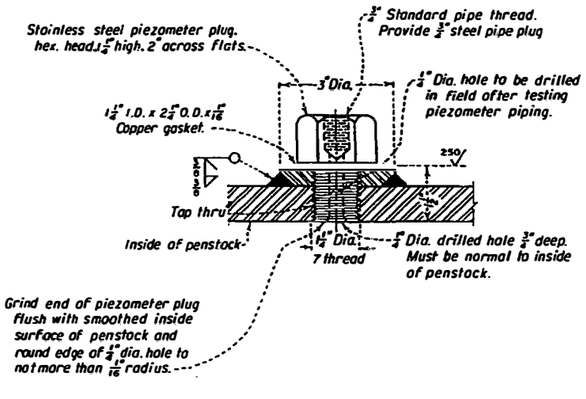
SLEEVE-TYPE COUPLED JOINT
EIGHT REQUIRED



PIEZOMETER SECTION



DETAIL I
Typical for all stiffener rings



PIEZOMETER CONNECTIONS

NOTE
Piezometer piping shown on Dwg. 459-D-263

7-26-62 O. N.C.P.	CHANGED FILLING PIPE CONNECTION TO AGREE WIT FACTURER'S DRAWINGS.
THIS DRAWING SUPERSEDES DWG. 459-D-25	

UNITED STATES
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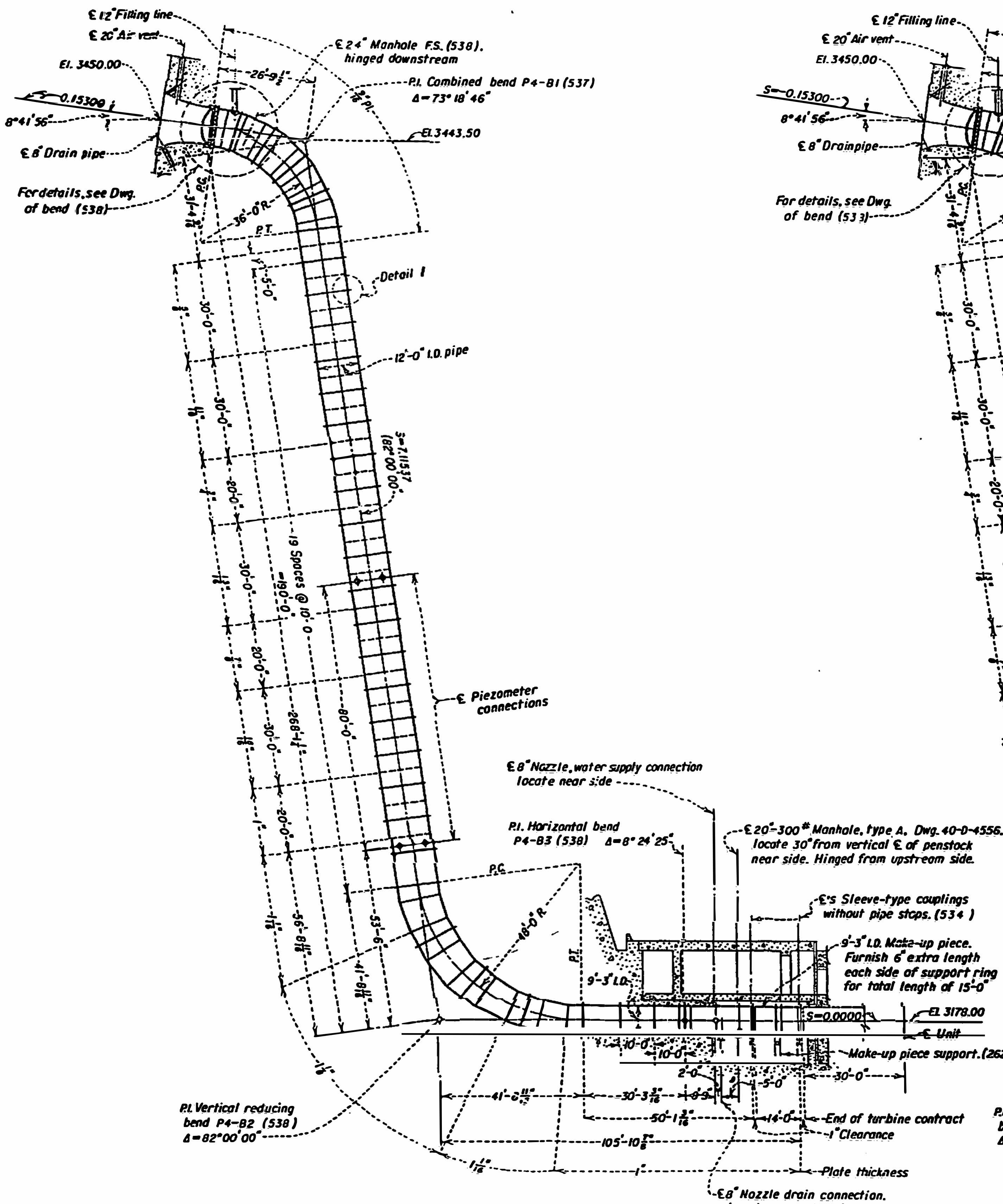
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-MON

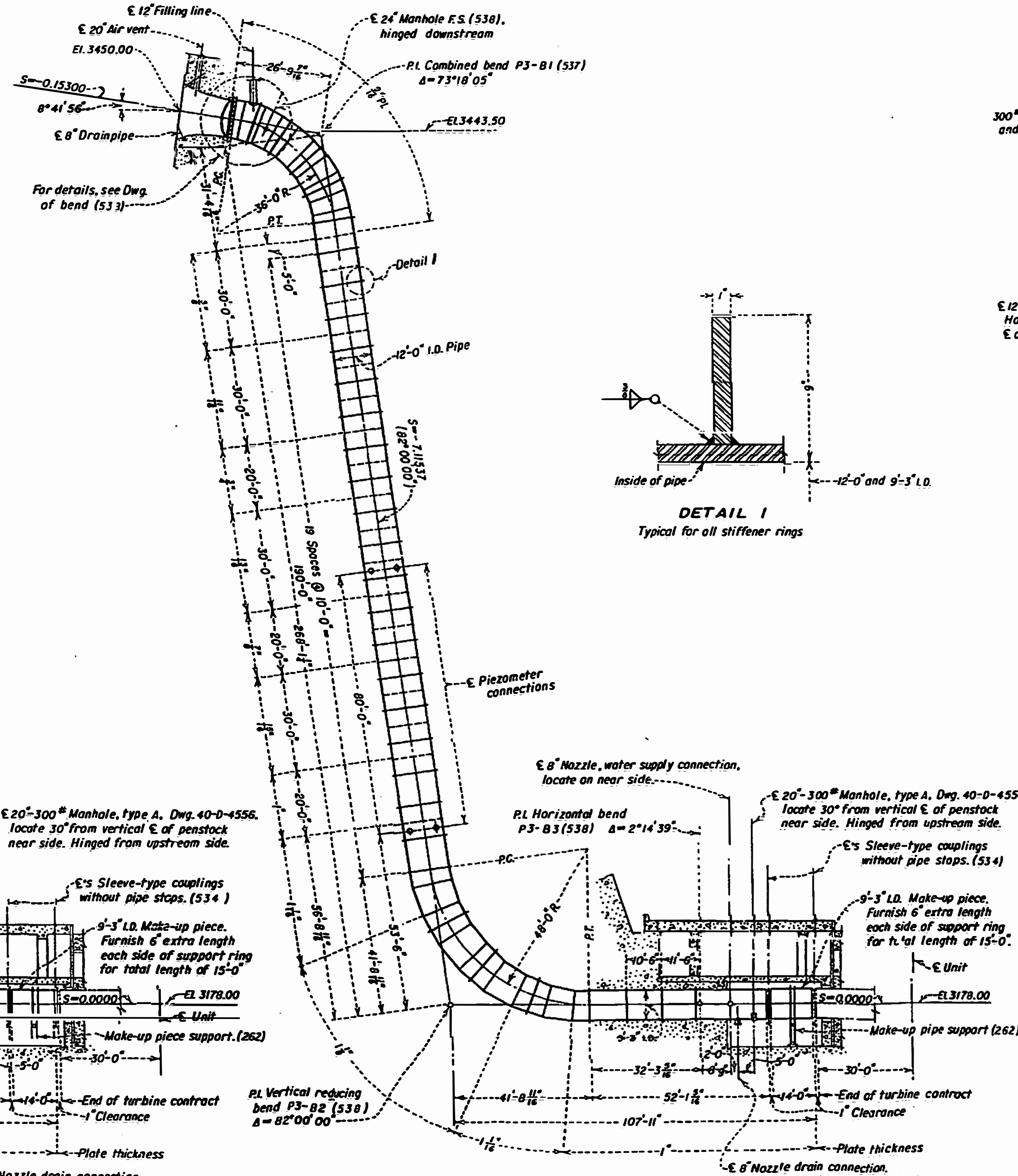
YELLOWTAIL DAM
PENSTOCKS
PROFILES No. 1 AND No. 2

DRAWN C.P.M.-L.M.N.	SUBMITTED W.H. Stranger		
TRACED R.L.O.	RECOMMENDED F. Uglidenjer		
CHECKED W.R.L. M.P.	APPROVED H.C. Steele		
DENVER, COLORADO, NOV. 27, 1961		459-D-5	

-534

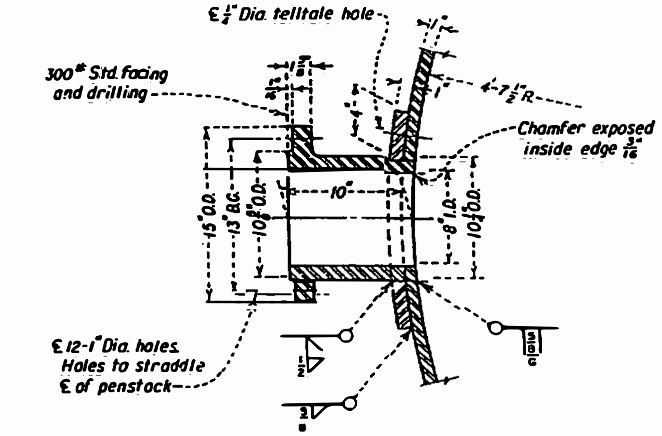


PROFILE PENSTOCK NO. 4



PROFILE PENSTOCK NO. 3

DETAIL I
Typical for all stiffener rings



8 INCH NOZZLE
FORGED OR ROLLED STEEL
EIGHT REQUIRED

NOTE
Piezometer piping shown on Dwg. 459-D-263.

7-26-62 D. N.C.P.	CHANGED FILLING PIPE CONNECTION TO AGRE[E] MANUFACTURER'S DRAWINGS.

THIS DRAWING SUPERSEDES DWG. 459-D-

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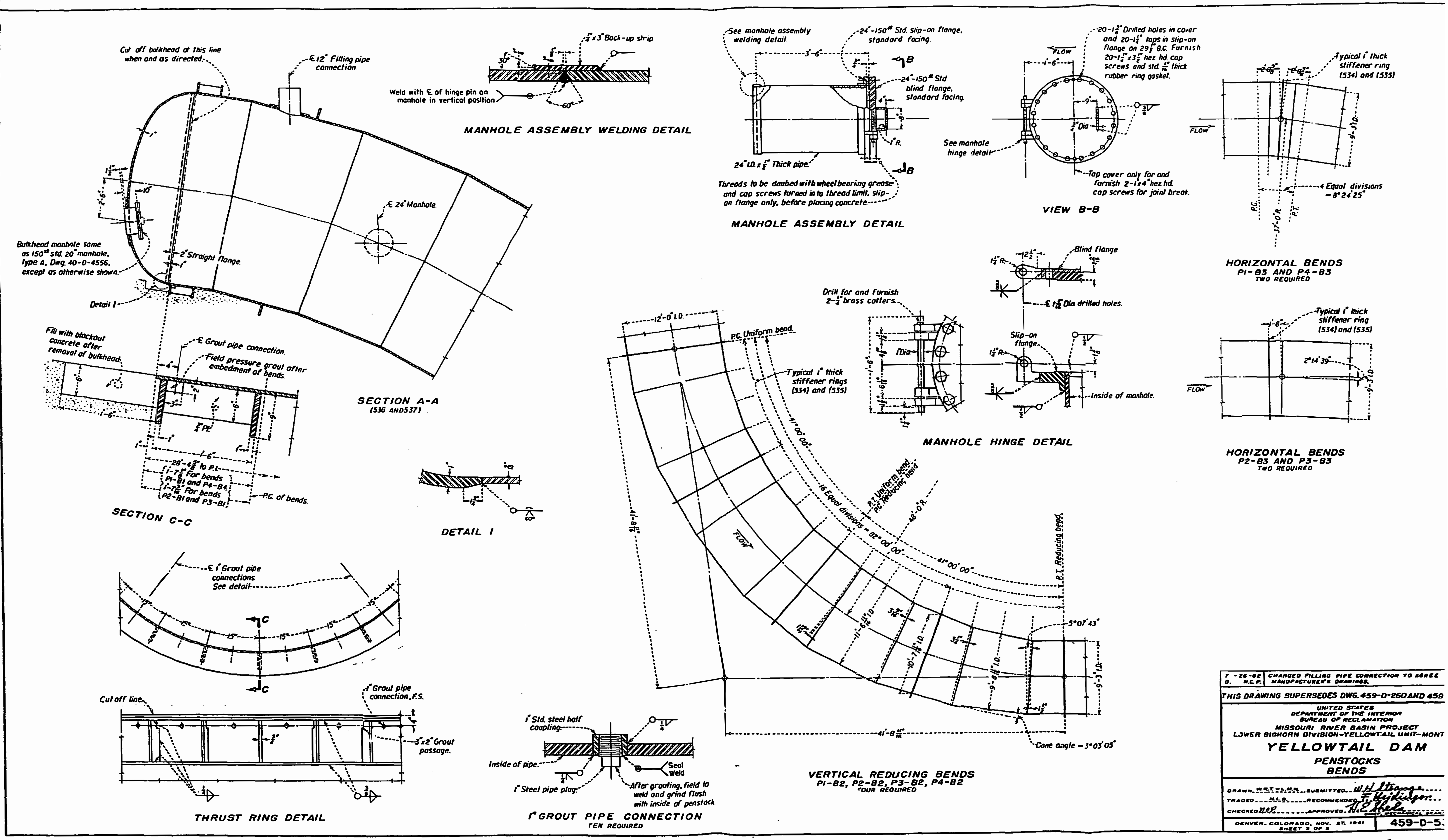
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-

YELLOWTAIL DAM
PENSTOCKS
PROFILES No. 3 AND No.

DRAWN C.P.M. L.M.N. SUBMITTED [signature]
TRACED E.D.R. RECOMMENDED [signature]
CHECKED [initials] APPROVED [signature]
CHIEF MECHANICAL
DENVER, COLORADO; NOV. 27, 1961 459-


Cut off bulkhead at this line when and as directed.
℄ 12" Filling pipe connection.
Bulkhead manhole same as 150# std. 20" manhole, type A, Dwg. 40-D-4556, except as otherwise shown.
2" Straight flange.
℄ 24" Manhole.
Detail 1
SECTION A-A
(536 AND 537)
Fill with blockout concrete after removal of bulkhead.
℄ Grout pipe connection.
Field pressure grout after embedment of bends.
28'-4 3/8" to P.I.
P.C. of bends.
SECTION C-C
1/2" x 3" Back-up strip
Weld with ℄ of hinge pin on manhole in vertical position.
MANHOLE ASSEMBLY WELDING DETAIL
DETAIL 1
See manhole assembly welding detail.
24"-150# Std. slip-on flange, standard facing.
24"-150# Std. blind flange, standard facing.
24" I.D. x 1/2" Thick pipe.
Threads to be daubed with wheel bearing grease and cap screws turned into thread limit, slip-on flange only, before placing concrete.
MANHOLE ASSEMBLY DETAIL
See manhole hinge detail.
Tap cover only for and furnish 2-1x4" hex hd. cap screws for joint break.
VIEW B-B
Typical 1" thick stiffener ring (534) and (535)
4 Equal divisions = 8°24'25"
HORIZONTAL BENDS
P1-B3 AND P4-B3
TWO REQUIRED
HORIZONTAL BENDS
P2-B3 AND P3-B3
TWO REQUIRED
Blind flange.
Drill for and furnish 2-1/4" brass cotters.
Slip-on flange.
Inside of manhole.
MANHOLE HINGE DETAIL
P.C. Uniform bend.
Typical 1" thick stiffener rings (534) and (535)
16 Equal divisions = 82°00'00"
41°00'00"
P.T. Uniform bend
P.C. Reducing bend
48'-0" R.
P.T. Reducing bend.
FLOW
5°07'43"
Cone angle = 3°03'05"
VERTICAL REDUCING BENDS
P1-B2, P2-B2, P3-B2, P4-B2
FOUR REQUIRED
℄ 1" Grout pipe connections See detail.
Cut off line.
1" Grout pipe connection, F.S.
3"x2" Grout passage.
THRUST RING DETAIL
1" Std. steel half coupling.
Inside of pipe.
1" Steel pipe plug.
Seal weld
After grouting, field to weld and grind flush with inside of penstock.
1" GROUT PIPE CONNECTION
TEN REQUIRED
CHANGED FILLING PIPE CONNECTION TO AGREE MANUFACTURER'S DRAWINGS.
THIS DRAWING SUPERSEDES DWG. 459-D-260 AND 459
UNITED STATES
DEPARTMENT OF THE INTERIOR
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MISSOURI RIVER BASIN PROJECT
LOWER BIGHORN DIVISION-YELLOWTAIL UNIT-MONT
YELLOWTAIL DAM
PENSTOCKS
BENDS
DENVER, COLORADO, NOV. 27, 1961
SHEET 3 OF 3
459-D-5
-538

Ultrasonic flowmeter Installation Guidelines for Tiber Dam Outlet Works

For the 72- and 22-in-diameter outlet pipes at Tiber Dam the following ultrasonic flowmeter installation recommendations are made with in accordance with ANSI/ASME standard MFC-5M-1985. Note that PTC-18 does not apply to this application because to my knowledge there are no potential acceptance test requirements.

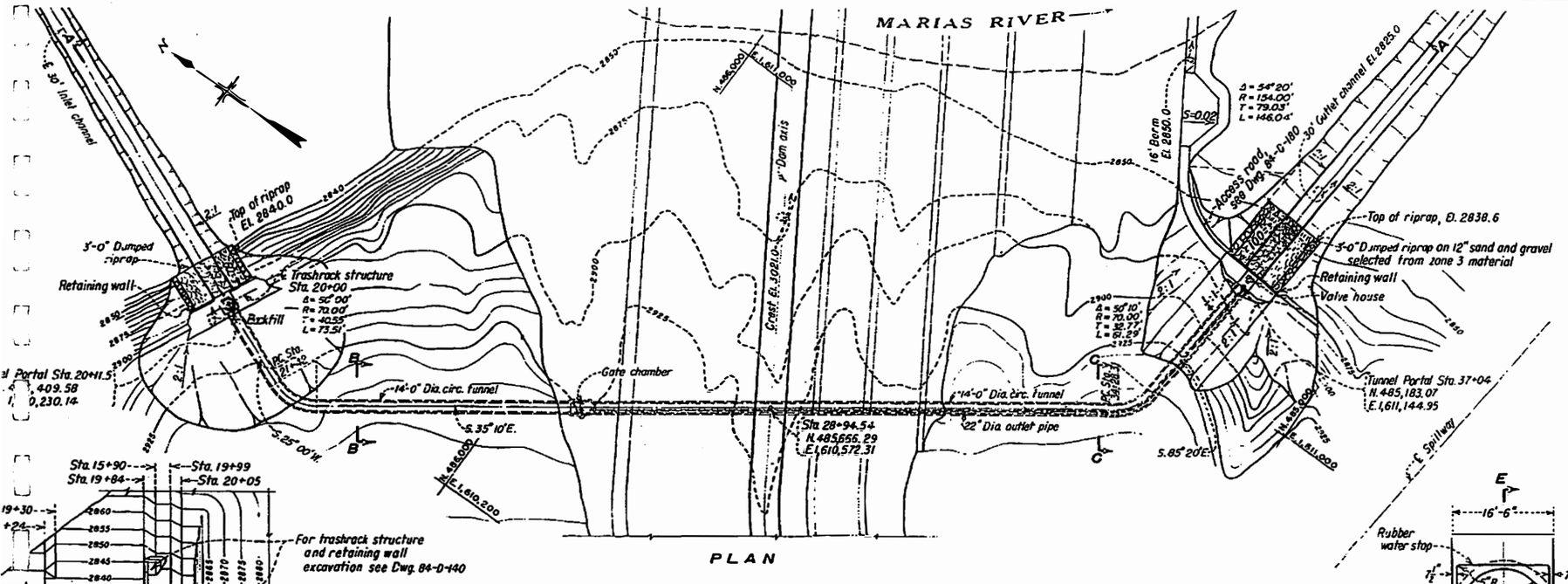
- Installation locations can be selected according to the guidelines of at least 10 pipe diameters of straight pipe upstream of the site and 3 pipe diameters of straight pipe downstream from any obstructions which may affect the velocity distribution at the measurement section. Because of the length of both pipelines site selection should be made according to accessibility to power, adequate work space, etc.

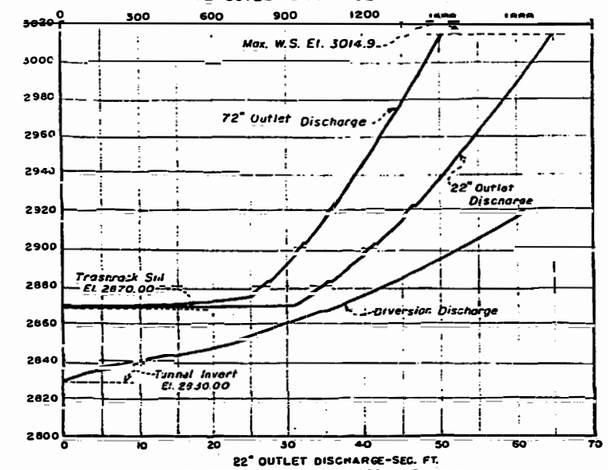
- There are many available one-path ultrasonic flowmeters. Some are clamp-on transducer (externally mounted) systems, while wetted transducer systems are also available. I would recommend a wetted transducer system because they are more accurate and they do not require a calibration of pipe wall or liner material thicknesses or temperature compensation.

- There are several alternative methods of measuring flow on these two pipelines. However, if your accuracy requirements do not require accuracies of ±1.0 percent of the actual discharge you can use a 1 or 2 path system and attain accuracies in the ±1.0 to 5.0 percent range.

- An Accusonics system for one or two acoustic paths would cost $11,000 and 12,100, respectively. Note that these costs are for equipment only and do not include installation expenses.

TIBER





DISCHARGE CURVES

NOTE

Because of additions to the river outlet works (Specifications No. DC-4563), this drawing is superseded in part by the following drawings:

84-D-367 thru 372
84-D-374 and 375
84-D-377 and 378

NOTES

The following items not shown: reinforcement, trashracks, electrical conduits and apparatus, control piping and apparatus, ventilating system, sump pump, miscellaneous piping and drains and reservoir level gage.

Concrete finishes in tunnel to be F2 for formed surfaces and U2 for unformed surfaces.

Design based on concrete of 3000 lbs per sq. inch compressive strength at 28 days.

Second stage concrete

Type NI metal seals will be placed in all transverse construction joints in tunnel lining.

REFERENCE DRAWINGS

TRASHRACK STRUCTURE	84-D-140
GATE CHAMBER	84-D-141
VALVE HOUSE	84-D-142
TUNNEL REINFORCEMENT	84-D-145
RESERVOIR LEVEL GAGE PIPING	84-D-107
METAL SEAL DETAILS	40-D-4510
OUTLET PORTAL DETAILS	84-D-180

10-22-58 D. A. 218	ADDED DISCHARGE CURVE AND NOTES

UNITED STATES
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MISSOURI RIVER BASIN PROJECT
MARIAS DIVISION-LOWER MARIAS UNIT-MONT.

TIBER DAM

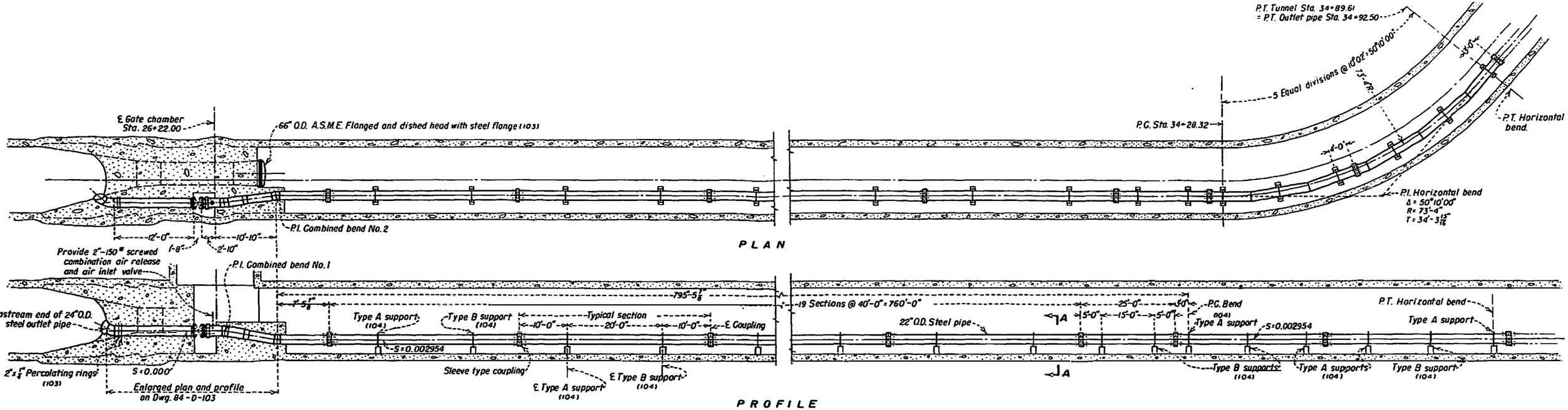
RIVER OUTLET WORKS PLAN AND SECTIONS

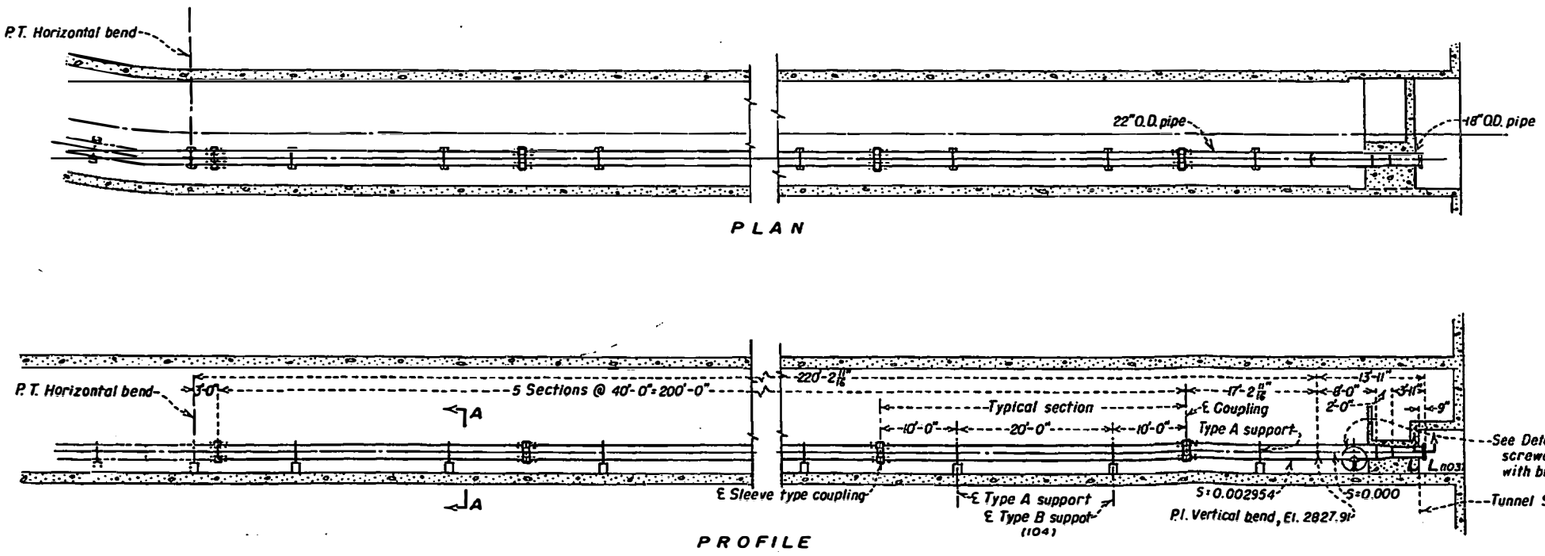
DRAWN EGR-EMB-JP SUBMITTED
TRACED R.V.S. RECOMMENDED
CHECKED APPROVED
Chief Engineer

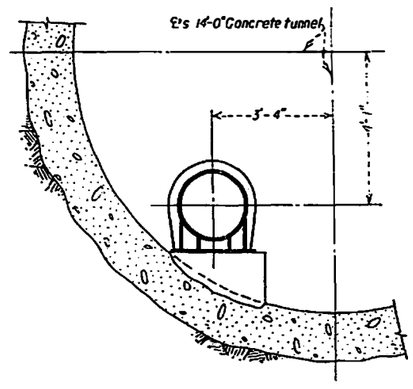
DENVER, COLORADO, MAR. 6, 1953

84-D-90

TIBER







NOTE
Plate thickness 1/4" unless otherwise indicated.

LIST OF DRAWINGS

BENDS - FLANGES - BULKHEAD	84-D-103
SUPPORTS	84-D-104

REFERENCE DRAWINGS

RIVER OUTLET WORKS:

PLAN AND SECTIONS	84-D-90
STRUCTURES	84-D-91

7-20-54 D MF	ADDITION OF AIR VALVE.

UNITED STATES
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MISSOURI RIVER BASIN PROJECT
MARIAS DIVISION-LOWER MARIAS UNIT-MONT.

TIBER DAM
RIVER OUTLET WORKS-STEEL PIPE PLAN AND PROFILE

DRAWN	C.B.	SUBMITTED	L. N. McClellan
TRACED	M.O.B.	RECOMMENDED	O. L. Rice
CHECKED	R.V.S.	APPROVED	L. N. McClellan, CHIEF ENGINEER

DENVER, COLORADO, APRIL 14, 1950

84-D-102

RELEASED 3-22-54 E.E.C.

TIBER DAM

PLAN
STA. 32+43.63 TO STA. 32+91.32

PROFILE
STA. 32+31.63 TO STA. 32+91.32

SECTION A-A

SECTION B-B

SECTION C-C

TYPICAL PIPE STRAP

DETAIL D

DETAIL E

SECTION E-E

SECTION F-F

NOTES

LIST OF DRAWINGS

13" STEEL PIPE	
GENERAL ARRANGEMENT	84-D-360
REINFORCEMENT	84-D-361
SUPPORT AND ANCHOR RINGS	84-D-362
TUNNEL ROADWAY	
SHEET 1 OF 3	84-D-370
SHEET 2 OF 3	84-D-371
SHEET 3 OF 3	84-D-372
STANDARD DRAWINGS	
3-PIECE MANHOLE	40-D-4553

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

DRAWN CHW
TRACED
CHECKED P&T

SUBMITTED
RECOMMENDED
APPROVED

84-D-367

Accusonics Flowmeter costs — Canyon Ferry

Enter: Number of acoustic planes= 3 — 4-PATH SYSTEMS ON THREE PENSTOCKS

number of acoustic paths 12

Item	unit price	total cost
Model 7500/8-paths max	$16,300.00	$16,300.00
Model 7520/8-paths max (upto six 7520's/7500	$7,500.00	$7,500.00
Model 7601 xdcrs (2/path)	$550.00	$13,200.00
Model 7641 mounts (2/path)	$550.00	$13,200.00
Xdcr cables and connector (2/path)	$150.00	$3,600.00
Model 7642 xdcr installation tool	$750.00	$750.00
	sum	$54,550.00
	GSA disc (6%)	$51,277.00

Accusonics Flowmeter costs — Helena Valley Pumping Plant

Enter: Number of acoustic planes= 2 — 4-PATH SYSTEMS ON TWO PIPES

number of acoustic paths 8

Item	unit price	total cost
Model 7500/8-paths max	$16,300.00	$16,300.00
Model 7520/8-paths max (upto six 7520's/7500	$7,500.00	$0.00
Model 7601 xdcrs (2/path)	$550.00	$8,800.00
Model 7641 mounts (2/path)	$550.00	$8,800.00
Xdcr cables and connector (2/path)	$180.00	$2,880.00
Model 7642 xdcr installation tool	$750.00	$750.00
	sum	$37,530.00
	GSA disc (6%)	$35,278.20

Accusonics Flowmeter costs — Yellowtail Dam Penstocks

Enter: Number of acoustic planes= 5 — 1 8-PATH SYSTEM AND 3 4-PATH SYSTEMS

number of acoustic paths 20

Item	unit price	total cost
Model 7500/8-paths max	$16,300.00	$16,300.00
Model 7520/8-paths max (upto six 7520's/7500	$7,500.00	$15,000.00
Model 7601 xdcrs (2/path)	$550.00	$22,000.00
Model 7641 mounts (2/path)	$550.00	$22,000.00
Xdcr cables and connector (2/path)	$150.00	$6,000.00
Model 7642 xdcr installation tool	$750.00	$750.00
	sum	$82,050.00
	GSA disc (6%)	$77,127.00