UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PIPELINE DISCHARGE MEASUREMENTS WITH RADIOISOTOPES

Report No. Hyd-578

Hydraulics Branch
DIVISION OF RESEARCH

OFFICE OF CHIEF ENGINEER
DENVER, COLORADO

September 1967

Where approximate or nominal English units are used to express a value or range of values the converted metric units in parentheses are also approximate or nominal. Where precise English units are used the converted metric units are expressed as equally significant values. A table, conversion factors--British to metric units of measurement, is provided at the end of this report.

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ABSTRACT

The use of radioisotopes to measure waterflow is a part of the Bureau of Reclamation program to improve water measurement practices. Measurements were made in the Salt River Project irrigation system in concrete pipelines 2, 2.5, and 3.5 ft in dia. A pitot velocity method was used to measure the discharge for comparison with the discharge measured by the sudden injection or total count radioisotope method. The sample tank and infinite medium techniques were used for counting the radioisotope activity. Accuracy of the radioisotope measurement method could not be evaluated extensively because of the limited number of tests. Although relatively good repeatability was shown in measuring a given discharge by the radioisotope method, discharges computed by the 2 methods differed by -7.3 to -15.7%.

DESCRIPTORS-- *discharge measurement/ *radioactive isotopes/ tracers/ field tests/ mixing/ pipes/ *radiation measurement/ velocity/ geiger counters/ test procedures/ pitot tubes/ concrete pipes/ pipelines/ injection
IDENTIFIERS-- mixing length/ irrigation water/ Salt River Project, Ariz/ scintillation counters/ *total count method/ gold isotopes/ accuracy/ sudden injection method

FOREWORD

The investigation reported herein was a cooperative effort of many persons. Facilities and people for assistance in the field work were provided by the Salt River Project Water Users Association, Phoenix, Arizona, cooperating with Bureau of Reclamation regional and area offices. Mr. T. W. Lynch (dba) Lynch Radiation Services, Los Angeles, California, controlled the use of the radioisotope under contract to the Regional Office, Boulder City, Nevada. The study was coordinated in the Division of Research of the Denver Office of the Bureau by personnel from the Chemical Engineering and Hydraulics Branches. Mr. R. L. Hansen provided technical assistance in the field for radiological measurements.

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INTRODUCTION

When water is scarce, it must be conserved just as any natural resource. Conservation requires accurate measurement of flows to account for the use and to equitably distribute the supply.

As part of the Bureau program, new water-measurement devices and methods are continually being developed and older devices are being modified, adapted, and improved to obtain a higher measurement accuracy. Increased emphasis has been placed on the evaluation of new and improved water-measurement devices and procedures, including the radioactive tracer method.

The development of the radioisotope method progressed in these tests in 1964 as a result of a series of pipeline discharge measurements made on the Salt River Project irrigation system near Phoenix, Arizona. Discharges measured by the radioisotope method were checked using a primary measurement, the pitot velocity method. In addition to the discharge measurements, resistance-to-flow coefficients were computed for the concrete pipe from head loss measurements made during the flow measurement tests. Benefits were thus achieved in two separate programs, (1) accuracy of measuring discharge by the radioisotope method and (2) measuring flow resistance coefficients of concrete pipe. This report presents the results of the discharge measurements. The results of the resistance coefficient measurements were published by the Salt River Project.1/

SUMMARY

Three pipe test sections, having 24-, 30-, and 42-inch diameters, were selected for the comparison of the radioisotope and pitometer

1/Report on Resistance Coefficient Tests Cast-in-place Concrete Pipe, T. T. Wilson, Jr. and Edib Kidar, Salt River Project, Phoenix, Arizona, December 1966.

discharge measuring methods. A pipe test section included a length of concrete pipe, inflow junctions where well water entered to supplement the flow of surface irrigation water, and pipeline turnout structures, Figures 2 and 3. Pipeline flows are usually held constant for periods of several days or weeks; thus, the system was well suited for tests requiring a stabilized flow.

A pitometer was used as the primary method of measuring the discharge through the pipes. The pitometer is a special form of pitot tube for measuring velocity head. The procedures followed in the use of the pitometer were recommended by the ASME power test code.

The sudden injection or total count radioisotope method was used as the second means of discharge measurement in this study. A known quantity of radioisotope (Gold 198) was introduced into the pipe flow in a comparatively short time, Figures 5A, 6A, and 7A. The concentration of the tracer was measured at a radioisotope counting and sampling cross section, located downstream near the position of the pitometer, where the tracer was thoroughly mixed with the flow.

The concentration of radioisotope in the water mixture was measured by two different techniques: (1) continuous withdrawal of water from the pipe through a "sample tank" containing a detector, and (2) immersion of the detector in the waterflow to represent an "infinite medium," Figure 7B. The "sample tank" technique provides a small fixed volume of water surrounding the detector. The detector is calibrated in the tank using known concentrations and then is used in the same tank to measure the concentration of radioisotope-water mixture from the pipe.

The "infinite medium" technique is different in that a large volume of a homogeneous mixture of water and tracer around the detector, as occurs in a canal, is provided during calibration. The container representing the canal during calibration was large enough that any increase in the water volume surrounding the detector would not change the counting rate.

The pipe discharge Q was computed for the pitometer method by integration of the velocity traverse

$$Q = \int^{A} v\,dA.$$

Discharges were computed for the radioisotope method by the equation

$$Q_r = \frac{AF}{N}.$$

Thus, if the velocity and radioisotope methods have the same accuracy of measurement and are capably applied, Q_v should equal Q_r.

The discharges measured by the radioisotope method were compared to those measured by the pitometer because procedures for using the pitometer have been published in the ASME Power Test Codes for Hydraulic Prime Movers. No such code existed for the radioisotope method at the time of the measurements. In all discharge measurements, the radioisotope method of measurement indicated more water than the pitometer method, Table 1, Column 6. Differences in the discharge measurements ranged from -7.3 to -15.7 percent. The minimum difference of -7.3 percent between the two methods occurred for the smallest discharge and pipe.

The accuracy of the radioisotope method could not be extensively evaluated because of the limited number of measurements. Errors, possible in both methods, may have prevented closer agreement between the discharges measured by the velocity and radioisotope techniques. Relatively good repeatability in measuring the discharge by the radioisotope method was obtained. Carefully controlled measurements by the radioisotope method and another method having high order accuracy should be made in future tests to establish the probable accuracy of the radioisotope method.

INVESTIGATION

Pipeline Distribution System Description

The Salt River Project irrigation system surrounds the city of Phoenix, Arizona, with irrigation canals, laterals, ditches, and underground pipe. The system is supplied with water from a series of reservoirs, of which the largest is impounded by Roosevelt Dam, Figure 1. Because of the extensive urban developments, many miles of concrete pipe have been installed underground to prevent encumbering the residential areas with open waterways that might be unsightly and dangerous. These pipelines provided an excellent test ground for the determination of resistance-to-flow coefficients for cast-in-place concrete pipe and the opportunity to compare discharge measuring methods.

Fifteen pipe test sections ranging in size from 24 to 54 inches in inside diameter were selected for resistance coefficients tests and 11 were inspected, cleaned, and prepared for test in the spring of 1964. A pipe test section includes a length of pipe, inflow junctions where well water enters to supplement the surface supply of irrigation water, and pipeline turnout structures, Figures 2 and 3. Operational requirements of the system prevent varying flow rates over short intervals of time to accommodate the testing program. Flows are usually held constant for periods of several days or weeks; thus, the system was very well suited for tests requiring a stabilized flow. Three different pipes having 24-, 30-, and 42-inch inside diameters were selected from the group of 15 for comparing the pitot-velocity and radioisotope techniques of discharge measurement.

Velocity Method of Discharge Measurement

Using procedures governed by recommendations in the ASME power test codes, the velocity distribution was measured in the test pipes. These data were then used to compute the discharge. Velocities were measured with a pitometer, a special form of a pitot tube. A U-tube manometer was used to measure the differential head created by the flow of water past the specially constructed pair of orifices in the single tube of the pitometer. One of the orifices reacts to the total head (velocity head plus pressure head) and the other orifice reacts only to the pressure head. The differential head indicated in the U-tube is proportional to the velocity head of the flowing water at tip of the pitometer.

Velocities in the cross section were measured on two diameters 90° apart, at the downstream end of the straight pipe test sections, Figure 8. The measuring cross sections were located at least five pipe diameters upstream from the pipe turnout structure. There were no bends or obstructions in the pipe upstream from the pitometer to cause nonuniform velocity distributions.

The area of the pipe at each velocity measuring section was computed from accurately measured internal diameters. The area was then divided mathematically into 5 equal concentric areas, Figure 4. The center between each of the concentric circles forming the boundary of the 5 equal areas was determined by computation. The center location of each of the areas was used to position the pitometer for 10 velocity measurements on each of the 2 diameters, 90° apart.

Differential head developed by the impact and pressure orifices of the pitometer is shown in the U-tube water manometer used to measure, Figure 8B. Velocities were computed from the differential head in the equation:

$$v = C\sqrt{2gH}$$

where C = the pitometer velocity coefficient established from a towing tank rating

v = velocity in fps

g = acceleration of gravity, fpsps

H = difference in pressure head from pitometer in feet of flowing water

An integration method was used to compute the discharge from the measured velocities. For a cylindrical pipe, there are two convenient ways of performing the integration and they both are based on the equation

$$Q = \int^{A} v dA.$$

The area of a pipe is $dA = 2\pi r dr = \pi d(r)^2$. The equation for the discharge becomes

$$Q = \pi \int_0^{R^2} v d(r^2) \text{ or } 2\pi \int_0^{R} (vr) dr$$

where

r is the radial distance to the point of velocity measurement, v is the velocity, and R is the radius of the pipe. The integrals may be evaluated graphically from a plot of v versus r^2, or vr versus r. The area under the curve is then measured and the result is multiplied by π or 2π.

The second method of integration was chosen for computing the discharge in this study. A computer program was written to perform the integration. For each successive pair of values of vr and r from the test data, points on a segment of a third degree polynomial were calculated using Newton's interpolation formula with central divided distance. A Newton-Cotes integration formula using five successive points on the polynomial was incrementally applied to numerically integrate the area under the curve. The result is the value of the integral,

$$\int_0^{R} vrdr$$

The discharge Q is then obtained by multiplying the integral by 2π. The computer program integrates the velocity traverse and computes a gross discharge (Q_g) for the pipe.

A reduction in the gross discharge was made for the presence of the pitometer rod in the cross section of the flow. The reduction was based on the projected area of the rod in the direction of flow when the orifices were at the center of the pipe. For the cylindrical rod of the pitometer, the area affecting the flow was taken as 1.25 times the projected area of the rod extended to the pipe center. A discharge reduction q was computed from the product of effective area (a) and the average velocity $\bar{V}$ in the pipe. The net discharge is $Q_v = Q_g - a\bar{V}$,

Table 1, Column 4. The value of $a\overline{V}$ was about 0.1 cfs (cubic feet per second) in the 24- and 30-inch pipes and about 0.4 cfs in the 42-inch pipe.

Radioisotope Method of Discharge Measurement

The sudden injection or total count method of radioisotope discharge measurement was used in this study. A known quantity A of radioisotopes, dissolved in a convenient volume v_1 of an acid-water mixture, was introduced into the pipe flow in a comparatively short time, Figures 5A, 6A, and 7A. At the measurement cross section downstream near the position of the pitometer, where the tracer was thoroughly mixed with the flow, the concentration of the tracer was determined from the gamma ray emissions detected and counted by Geiger-Muller or scintillation counters during the entire time of the tracer passage.

If the concentration of the injected radioisotope solution is C_1 and the concentration in an element volume dV in the stream at the time t is C, then

$$C_1 v_1 = \int (C - C_o) dV \qquad (1)$$

where dV is the elemental volume, and C_o is the natural concentration of the stream.

The total volume V passing the cross section is related to the discharge Q_r by $V = Q_r t$. Therefore, $dV = Q_r dt$, and

$$C_1 v_1 = Q_r \int^T (C - C_o)\, dt \qquad (2)$$

Because $C_1 v_1 = A$ and if C_o is the natural activity in the stream, the flow rate becomes

$$Q_r = \frac{A}{\int^T (C - C_o)\, dt} \qquad (3)$$

With a radiation detector arranged to indicate the total emissions or count received from the activity at the counting stations, the number of counts N is given by

$$N = F \int^T C\, dt \qquad (4)$$

where F is a constant of calibration dependent on the efficiency of the detector.

Inserting the value of the $\int^T C\,dt$ from equation (4) into equation (3) and accounting for the background concentration C_o we find that:

$$Q_r = \frac{AF}{N} \qquad (5)$$

Thus if the pitot velocity and radioisotope methods have the same accuracy of measurement, and are capably applied, Q_v should equal Q_r.

Test Preparations, Instruments, and Procedures

Test preparations by Salt River Project personnel for the resistance coefficient measurements included the construction of redwood-lined pits to provide access to the pipes at each end of each selected test reach. Piezometers were installed, one at the upstream and two at the downstream ends of each test reach using the following procedure. A gate valve and a 12-inch length of 1-inch standard pipe was sealed into a hole drilled through the concrete pipe wall. The end of the 1-inch pipe was made flush and smooth to form a piezometer orifice at the inside surface of the concrete pipe. The 1-inch pipe and valve also allowed the piezometer to be used for the insertion of the pitometer into the concrete pipe.

No special attachments on the pipe were necessary for the radioisotope discharge measurements. The radioactive tracer was added to the pipe flow through irrigation water inlets, Figure 5A, or through manholes intersecting the test pipe, Figures 6A and 7A. When introducing the radioisotope, the solution was put directly into the main body of the flow to be measured to prevent entrapment in an eddy or to prevent loss by chemical deposition on the sides of the pipe. The pipes were 4 to 6 feet below normal ground surface. When the pipe was flowing full and under pressure, the water partially filled the manhole. The column of water in the manhole could possibly retain a part of the injected radioisotope for an extended period of time. If this did happen, it would tend to increase the measured value of the flow. A plastic funnel and a length of plastic tubing were assembled and used to guide the isotope solution directly into the pipe flow, Figure 7A. For all of the introductions, the radioactive solution was poured and rinsed from a polyethylene bottle. Special precautions were maintained to prevent the loss of any part of the isotope solution by contact with the concrete enclosure, metal parts, or from splashing water.

Counting of the radioisotope-water mixture to determine N was accomplished by two different techniques: (1) continuous withdrawal of water from the pipe through a "sample tank" containing the detector, and (2) immersion of the detector directly in the water flow. Analysis and practice have shown that a sample of a homogenously mixed radiotracer in a stream can be withdrawn and counted as a discrete sample or as a small flowing sample. In a properly calibrated sample tank, the total count N measured from the small flowing sample can be used to compute the discharge of the main stream from

$$Q_r = \frac{F_t A}{N_t}$$

where F_t = calibration factor for the tank in counts per unit of radioactivity per unit of volume per unit of time (counts per microcurie per cubic foot per second).

The "sample tank" provides a small fixed volume of water surrounding the detector. Often the tank is made of metal, is cylindrical in shape, and permits direct contact of the detector with the radioisotope mixture withdrawn from the flow into the tank. In the Salt River Project measurements, however, the detector was placed in a dry well at the tank center, Figure 5B. The dry well diameter was about one-fourth inch larger than the 3-inch diameter of the detector case.

The radiation counting system was calibrated in the "sample tank" at the exact position of use to determine (F_t), Figures 5B, 6B, and 7B. This method of calibration was used because previous measurements in other tests showed a pronounced effect on the calibration factor F_t caused by the tank surroundings. A part of the original radioisotope solution was prepared and reserved specifically for this purpose.

Field calibration of the system was carried out as follows:

1. The sample tank was placed in the position of use and was then filled with water from the pipeline, using the portable pump later required for pumping a continuous sample.

2. The background count C_o was then measured for each system to be used by placing the detector in the dry well of the water-filled tank.

3. A 25-ml calibration quantity of Gold 198* (about 15 microcuries) was placed in the tank and air was slowly bubbled through the water for 20 to 30 minutes to uniformly mix the radioisotope and water. The concentration of the mixture of water and radioisotope was such that the emission rate would not exceed the counting capacity (counts per second) for the detector and counter.

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*Note: A and F (Equation 5) are related through the same calibration standard to eliminate the need for a determination of absolute values of radioactivity, normally calibrated in counts per second (counting rate) for a known dilution of radioisotope in water.

4. The detectors were again placed in the tank well and the gross count with respect to time (counting rate) was determined for the radioisotope added to the water and the background. A net count for the radioisotope-water mixture was computed from the background and gross count measurement. The net count rate was used with the measured tank volume and the amount of Gold 198 to determine the calibration factor F (counts per second per microcurie per cubic foot).

The total count N of the radioisotope-water mixture can also be measured by immersing the detector in the main stream of flow. A calibration factor must be obtained for conditions simulating the detector in a large volume of water. The stream discharge can be computed from

$$Q_r = \frac{F_v A}{N_s},$$

where

F_v = calibration factor from known large volume, and

N_s = total count from detector in stream.

Note: A and F are related through the same calibration standard to eliminate the need for a determination of absolute values of radioactivity, normally calibrated in counts per second (counting rate) for a known dilution of radioisotope in water.

The counting systems were calibrated for the "infinite medium" measurements by determining the counting rate of the detector submerged in a large container filled with a homogeneous mixture of water and radioisotope of known concentration. The concentration of the mixture was adjusted to give an emission rate that would not exceed the maximum counting rate of the system. The container size was large enough that any increase in the mixture volume surrounding the detector would not change the counting rate. Determination of the counting rate in this manner simulated the positioning of the detector in the pipe turnout structure, Figure 7B. The volume of the pipeline turnout structure exceeded the requirements for an "infinite" volume measurement of the radioisotope count.

Discharge Measurements and Results

A minimum of one pitometer traverse was made on each of two diameters in the 24-, 30-, and 42-inch test pipelines to determine the discharge by the velocity method, Figure 8. Pressure heads in the pipelines were continually measured throughout the velocity traverse measuring periods to determine the head loss and to monitor the steadiness of the flow. Care was exercised in both positioning of the pitometer and in the reading of the differential head developed by the orifices at the manometer, Figure 8B. Temperature corrections were made as necessary to convert the manometer reading to the equivalent head in feet of water. The results of these measurements, discharges for the three test pipes, are shown in Column 4 of Table 1.

Radioisotope discharge measurements were made concurrently with the velocity traverses. The isotope-water mixture was withdrawn from the test pipe in one case through a pitometer access pipe, Figure 5B, through a manway, Figure 6B, or through a pipe turnout structure, Figure 7B, to provide the flow for the sample tank. For discharge measurements by the "infinite medium" method, a detector was immersed in the flowing water in the pipe turnout, Figure 7B. Counting systems were located convenient to the position of the detectors and the count was manually recorded with respect to stopwatch time during the passage of the radioisotope-water mixture.

During the period required to make the velocity traverses there was sufficient time to make multiple discharge measurements by the radioisotope methods; two were possible in the 42-inch, four in the 24-inch, and seven in the 30-inch pipes, Table 2.

Discussion of Results

Discharges measured by the radioisotope method were compared to those measured by the pitometer. Measuring procedures for the pitometer have been established by an ASME code and the pitometer method can be considered a primary measurement. No such code existed for the radioisotope method at the time of the measurements. The equation used in the comparison was

$$\text{Percent difference} = \frac{Q_v - Q_r}{Q_v} \times 100$$

where Q_v = pitometer method discharge,

and Q_r = radioisotope method discharge.

The radioisotope method measured more water than the pitometer in each of the three pipes, Table 1, Column 6. Differences in the discharge measurements ranged from -7.3 to -15.7 percent. The minimum difference, -7.3 percent between the two methods, was measured for the smallest discharge and pipe.

The velocity range among the pipes was not large, 1.82 to 2.79 fps, but the discharge in the largest pipe was about three times greater than that in the smaller pipes. In each pipe the mixing length was sufficient, the minimum being about 410 diameters in 42-inch pipe, both for dispersion of the radioisotope in the pipe water and for establishing a good velocity distribution. The length available for mixing was about 410 diameters minimum and about 1,260 diameters maximum.

No major faults could be found in the application of the two methods of measurement but several possibilities for error existed in both methods. Because of the low velocity of flow, the velocity head measured by the manometer was small. Slight errors in reading the differential head may have resulted in too small a discharge. The pitometer velocity coefficient might have been in error in the low velocity range, again producing too small a discharge. There may have been slight errors in positioning the pitometer that resulted in errors in the computed discharges. The area of the pipe was computed from four measured diameters at each pitometer location, but this number may not have been enough to obtain an accurate area for the pipe.

Ten velocity measurements were made on each of the 2 pipe diameters. An increase in the number of measurements to give a better definition of the velocity curve, especially in the 2.5- and 3.5-foot pipes, might have improved the pitometer discharge measurement.

These factors had been thoroughly considered before the various quantities were measured however, and the procedures followed were believed to be sufficient to provide accurate results. All measurements were made as accurately as permitted by field conditions.

Several possibilities for error are inherent in the radioisotope method. Calibration of the system depends on the accurate measurement of the volume of radioactivity and on the calibration and positioning of the detector. The error in the computed discharge is directly proportional to the error made in measuring the quantity of the radioisotope. Calibration factors for the "sample tank" or "infinite medium" techniques can be in error because of errors in the measurement of the small volumes of radioisotope. Additional errors may be made in measuring the volume and thus the radioactive quantity to be added to the stream. Another error may be encountered in the counting of the emissions because of the random nature of the decay of the radioisotope. Loss of radioisotope after injection into the flow and before the mixing is complete can cause the indicated discharge to be larger than the actual flow. There was no evidence of loss in these studies; however, the fine clay and some sediments in the pipes may have absorbed some of the radioisotope.

In the 3.5-foot pipe, the radioisotope-water mixture was withdrawn through the pitometer access pipe to the tank from flow adjacent to the inside pipe wall, Figure 5B. In the 2- and 2.5-foot pipes the sample was withdrawn from the flow away from the pipe wall, Figures 6 and 7B. The method of withdrawing the sample or of obtaining the count of emissions (tank or infinite medium) did not result in major differences in the computed discharge rates.

The accuracy of the radioisotope measurements could not be extensively evaluated because of the limited number of measurements. Errors possible in both the velocity and radioisotope methods may have prevented closer agreement. The series did show relatively good repeatability in measuring the discharge by the radioisotope method, Table 2. Continued improvement in the techniques of application and better control of the field environment factors may result in better accuracy for the radioisotope method.

Although the procedure used to calibrate the sample tank in the field was time consuming, there was still sufficient remaining time to make more measurements with radioisotopes than with the pitometer. A variation, 1 to 6 percent, in the calibration factors was found for the sample tank located at the three pipes. This variation reaffirmed our previous finding that the effect of the tank surroundings must be considered for precise measurement of discharge.

Further testing will be required to establish the probable accuracy of the radioisotope method of measuring discharges at relatively low velocities occuring in concrete pipes. Comparisons of the values obtained by the radioisotope method with values obtained from other high order accuracy methods are needed to establish the reliability of the radioisotope method.

Table 1

SUMMARY OF DISCHARGE MEASUREMENTS
PITOMETER AND RADIOISOTOPE METHODS
Salt River Project
March-April 1964

Pipe size (1) ft	Mixing length (2) ft	Average velocity (3) fps	Discharge cfs Pitometer (4) Q_v	Discharge cfs Radioisotope (5) Q_r**	Percent difference $\frac{Q_v - Q_r}{Q_v}$ x 100 (6)
2	2,520	2.70	8.50		-7.3
		2.89		9.12 PM (Tank)	
		2.97		9.35 GM (Tank)	-10.0
		***(87° F)			
2.5	5,264	1.84	8.98		
		1.82	*8.89		
		2.08		10.15 PM (Tank)	-13.7
		2.12		10.34 GM (Infinite medium)	-15.7
		(90° F)			
3.5	1,440	2.79	24.94		
		3.07		27.48 PM (Tank)	-10.2
		(70° F)			

*Mean value 8.93 cfs.
**Mean values from Table 2 (PM--Photomultiplier detector, GM--Geiger-Muller detector).
***Water temperature.

Table 2

RADIOISOTOPES DISCHARGE MEASUREMENTS
Salt River Project
April 1964

Pipe	A	F	N	Q_r	Mean	System
2 feet	2.24	69.92	17,040	9.18)	9.12	PM A
			17,300	9.05)		
	2.22	12.66	3,130	8.96)	9.35	GM probe 2 in. calibrated tank
	2.20		2,860	9.73)		
2.5 feet	8.82	65.63	56,300	10.28-		PM A
	8.82	30.3	25,620	10.43(		GM probe 2 infinite medium
	8.71	65.63	57,400	9.96-		PM A
	8.71	30.3	25,900	10.20(		GM probe 2 infinite medium
	8.64	65.63	56,300	10.08-		PM A
	8.64	30.3	25,150	10.40(	10.34	GM probe 2 infinite medium
	8.60	65.63	54,900	10.28-	10.15	PM A
3.5 feet	14.42	68.86	35,350	28.00)	27.48	PM A
			36,700	26.95)		

PM A--Counting system with scintillation probe in sample tank.
GM--Counting system with Geiger-Muller probe in sample tank or in pipe flow (infinite medium).

Figure 1
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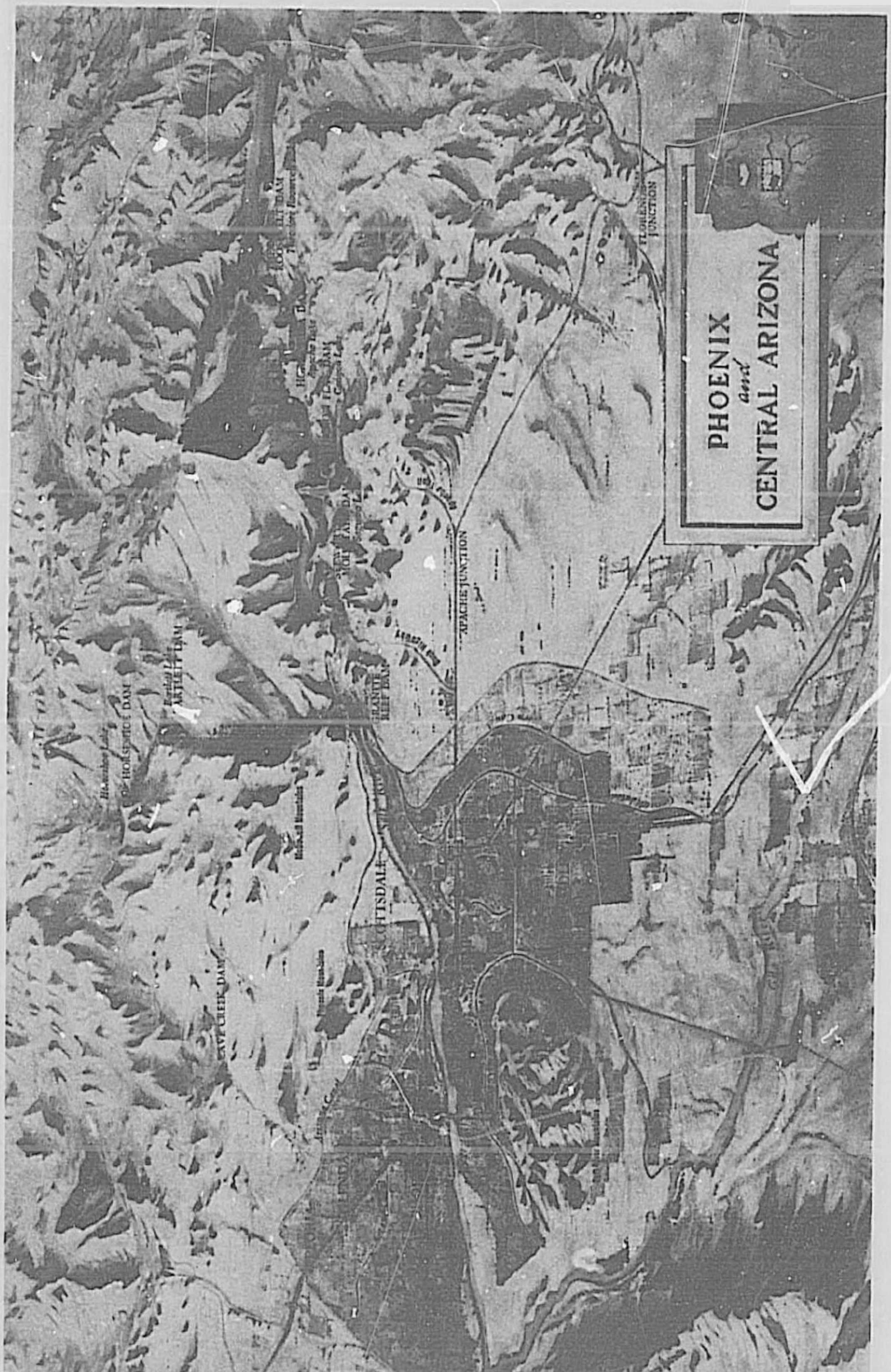
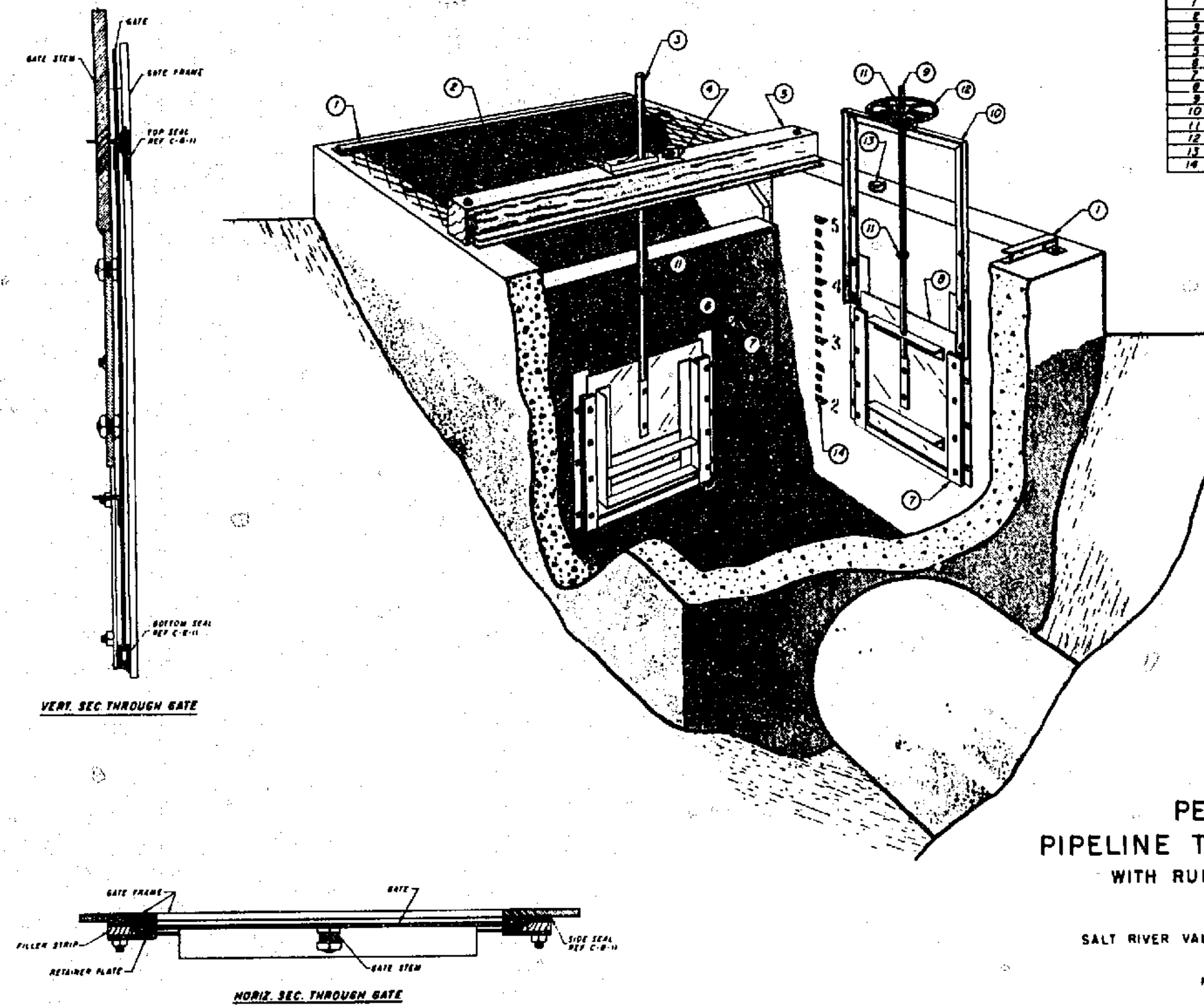


Figure 2
Report Hyd-578

ITEM	DES[illegible]PTION	REF. NO.
1	COVER GUIDE	B-54-20
2	PENNMETAL GRATING	C-8-46
3	FRICTION LIFT STEM	C-8-24
4	FRICTION LIFT ASSEMBLY	B-54-30
5	FRICTION LIFT GATE MANTEL	C-8-43
6	FRICTION LIFT STEEL GATE	C-8-26
7	STD. GATE FRAME	B-54-12
8	STD STEEL T O GATE	C-3-1094
9	SCREW STEM	C-8-25
10	STD MANTEL FOR T O GATE	C-3-1197
11	STOP COLLAR FOR STEMS	
12	10" HANDWHEEL	
13	VENT FILL CAP	
14	STAFF GAUGE	



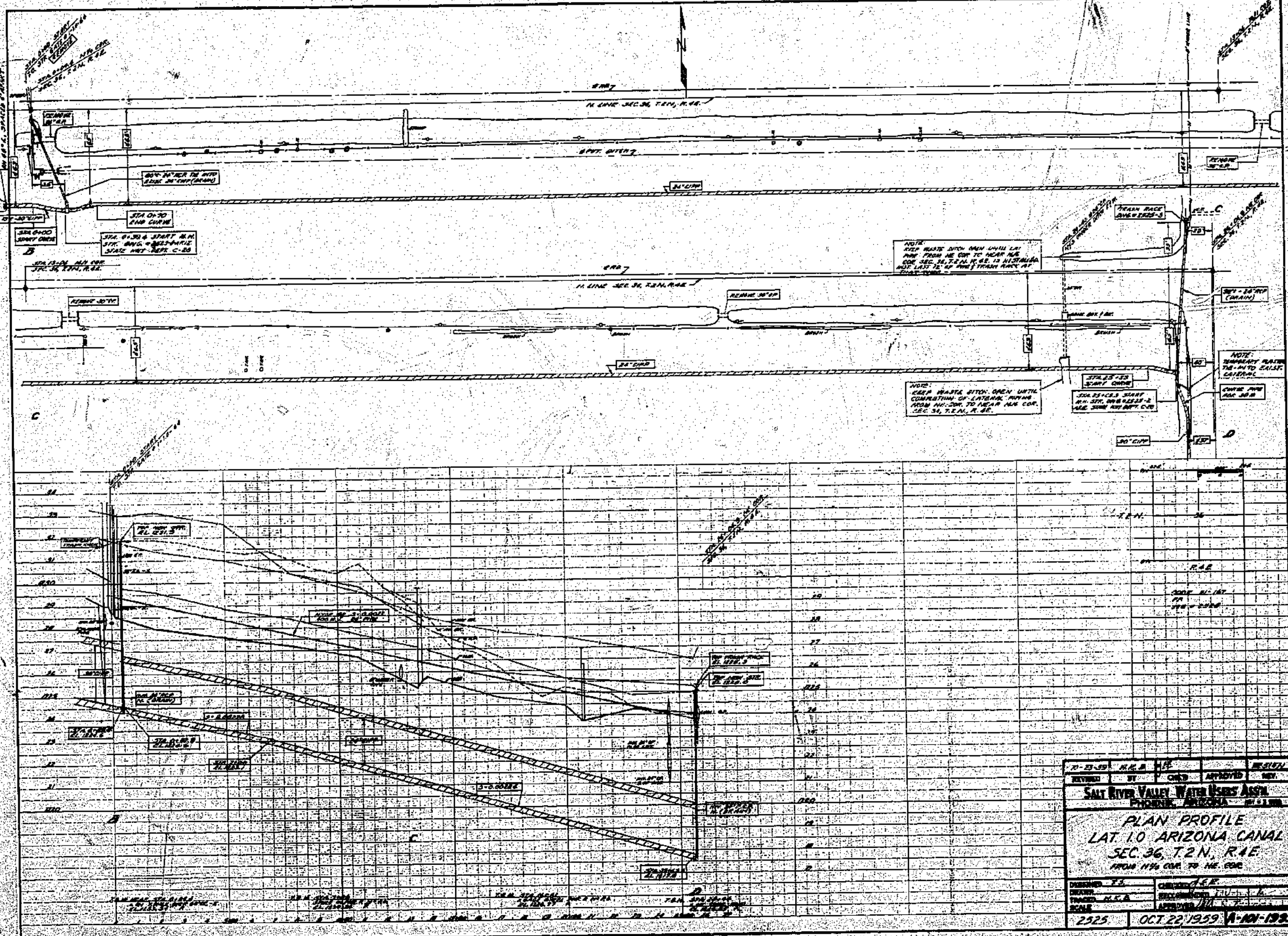
PERSPECTIVE
PIPELINE TURN OUT STRUCTURE
WITH RUBBER SEALED GATES

NOV 2 2 1963

SALT RIVER VALLEY WATER USERS ASSOCIATION
PHOENIX, ARIZONA
REVISED MAY 21, 1958

B-54-18

Figure 3
Report Hyd-578



FORM 7-120
REV. 3-50
BUREAU OF RECLAMATION

COMPUTATION SHEET

BY________ DATE________ PROJECT________________ SHEET No.____ OF____

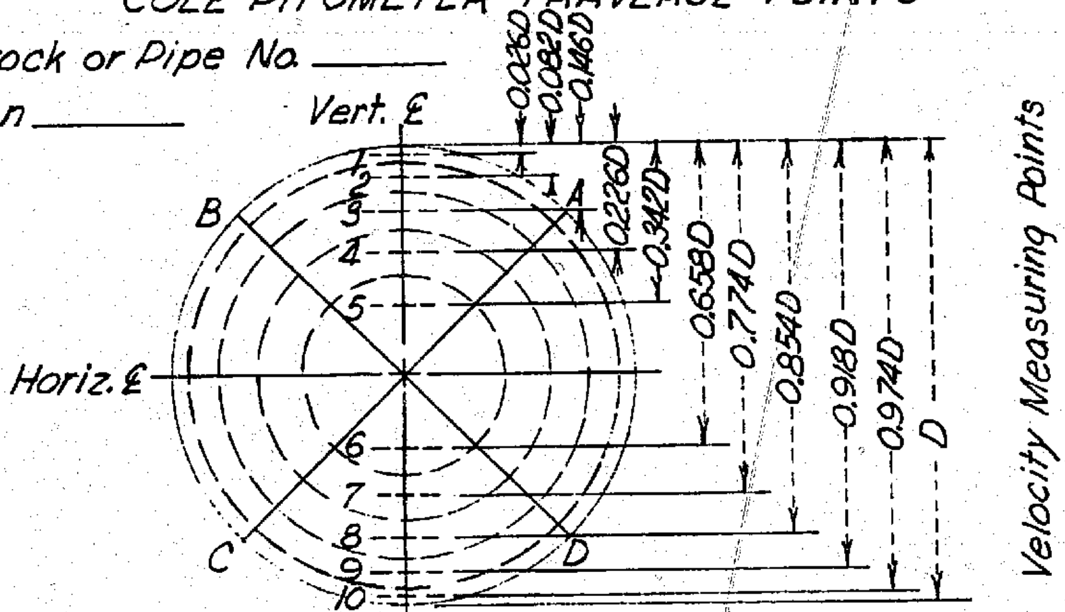
CHKD. BY______ DATE________ FEATURE________________ JOB No.________

OFFICE________________ DETAIL________________ FILE No.________

COLE PITOMETER TRAVERSE POINTS

Penstock or Pipe No. ______

Station ______



Downstream View

Locations of Pitometer Tip for 10-point Traverse

Dia. AC = ________ Vert. Dia. = ________

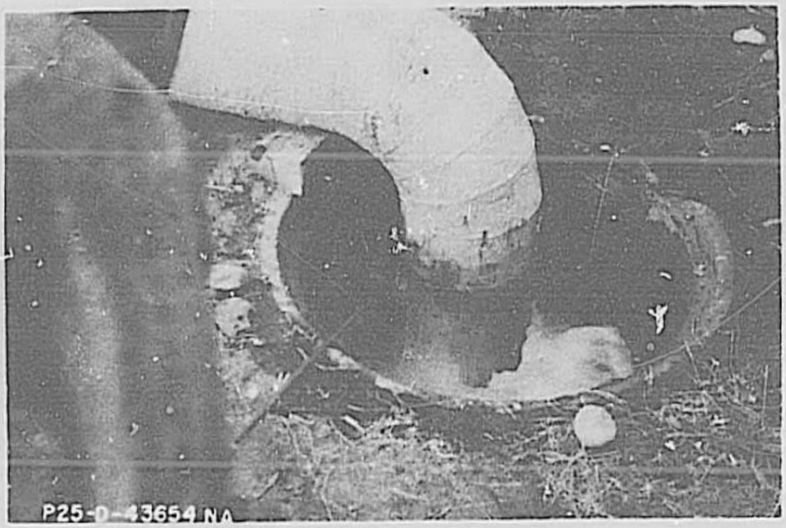
Dia. BD = ________ Horiz. Dia. = ________

Ave. Dia. = ________ Area = ________

Distance - wall to point

Point	Along Dia.______	Along Dia.______
1		
2		
3		
4		
5		
℄		
6		
7		
8		
9		
10		

Figure 5
Report Hyd-578



A. Tongs were used to introduce radioisotopes into 3.5-foot-diameter pipe with irrigation pump inflow of approximately 1.5 cfs.

B. Counting system for radioisotope discharge measurement at pitot tube station of 3.5-foot pipe. Radioisotope-water mixture was withdrawn from pipe through pitot tube access hole and pumped through sample tank (from right to left--counter on plank across pit, suction hose coming out of pit to pump, and sample tank). Water from sample tank was discharged in underground sand.

RADIOISOTOPE DISCHARGE MEASUREMENTS

Injection and Sampling Equipment for 3.5-foot Pipe

SALT RIVER PROJECT, ARIZONA

A. Tongs were used to introduce radioisotopes through manhole into 2-foot-diameter pipe.

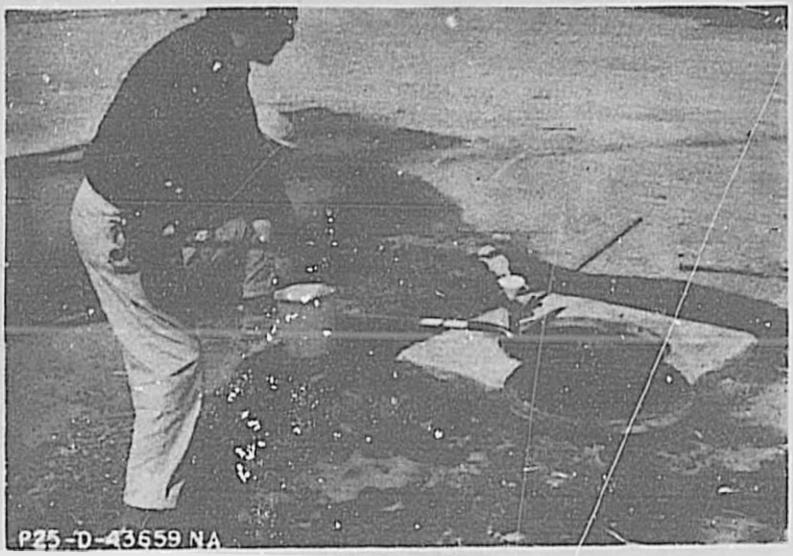
B. Simultaneous hydraulic and radioisotope discharge measurements in 2-foot pipe. Sample tank pump withdraws water from manhole at downstream end of 2-foot pipe.

RADIOISOTOPE DISCHARGE MEASUREMENTS

Injection and Sampling Equipment for 2-foot Pipe

SALT RIVER PROJECT, ARIZONA

Figure 7
Report Hyd-578



A. Radioisotope introduction through manhole into 2.5-foot pipe at junction of 2-foot pipe (note plastic funnel and plastic pipe that extends into 2.5-foot pipe).

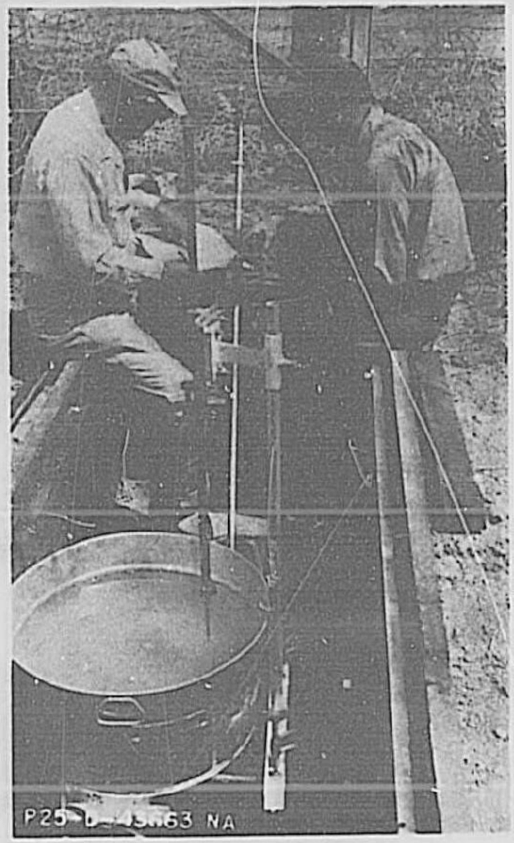
B. Scintillation and Geiger counting systems for sample tank and "infinite medium" discharge measurements.

(Scintillation probe used in sample tank. Geiger probe attached to rope in foreground and submerged in water in turnout)

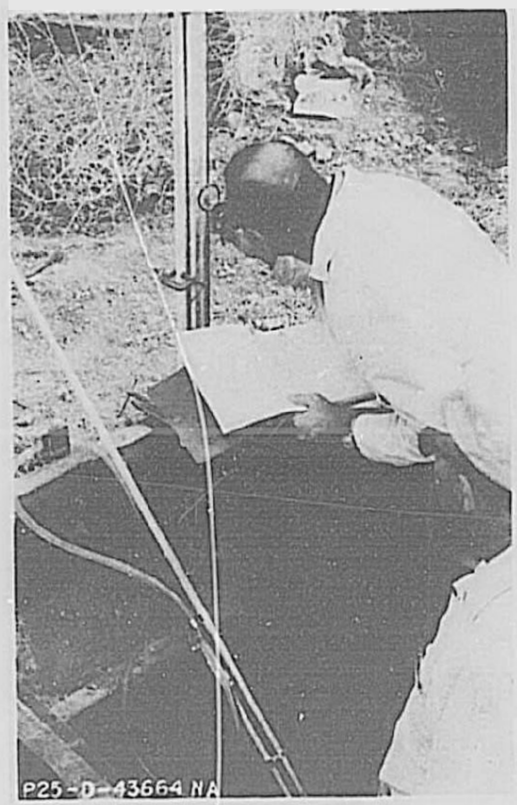
RADIOISOTOPE DISCHARGE MEASUREMENTS

Injection and Counting Systems in 2.5-foot Pipe

SALT RIVER PROJECT, AIRZONA



A. Pressure and velocity head measuring equipment at pitometer station in 2.5-foot-diameter pipe.



B. Reading pitometer differential head on manometer with magnifier.

RADIOISOTOPE DISCHARGE MEASUREMENTS

Velocity and Pressure Head Measuring Equipment

SALT RIVER PROJECT, ARIZONA

7-1750
(2-67)
Bureau of Reclamation

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, January 1964) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given on pages 10-11 of the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03*	Square centimeters
	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	946.358*	Cubic centimeters
	0.946331*	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985 x 10^6	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582 x 10^7	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873 x 10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482 x 10^{-5}*	Dynes

Multiply	By	To obtain
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.092903*	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

ABSTRACT

The use of radioisotopes to measure waterflow is a part of the Bureau of Reclamation program to improve water measurement practices. Measurements were made in the Salt River Project irrigation system in concrete pipelines 2, 2.5, and 3.5 ft in dia. A pitot velocity method was used to measure the discharge for comparison with the discharge measured by the sudden injection or total count radioisotope method. The sample tank and infinite medium techniques were used for counting the radioisotope activity. Accuracy of the radioisotope measurement method could not be evaluated extensively because of the limited number of tests. Although relatively good repeatability was shown in measuring a given discharge by the radioisotope method, discharges computed by the 2 methods differed by -7.3 to -15.7%.

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