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TITLE

HWO CR DUAL CHANNEL CROSS FLOW STUDIES

PROGRAM

HWO CR

SUBACCOUNT TITLE

Hydraulic and Mechanical Test

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STATEMENT OF PROBLEM

Evaluate three noise analysis methods for determining cross flow and mixing. Determine quantitatively the cross flow for a dual channel single cross flow configuration.

ABSTRACT:

Three methods were evaluated for the measurement of cross flow. Both the resistance and correlation method yielded the cross flow ratio Q_x/Q_z . The resistance method takes less time to run and analyze and produces more data points than the correlation method. The correlation method is not applicable to multi-channel tests. The model method could not be properly evaluated because of the relatively large cross flow in the dual channel. This method remains as a tool for analyzing experimental results

The Q_x/Q_z ratio for the average of the 4, 6 and 8 gpm flow rates and an average gap of 4 mils is

$$Q_x/Q_z = 0.294 \pm 0.0371$$

The quantitative cross flow M at a flow velocity of 26 ft per second and water at 102°F in the dual channel is

$$M = 0.326 \text{ \#/sec/ft} \pm 12.6\%$$

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I. OBJECTIVE

This experimental study evaluates three noise analysis methods for determining cross flow and mixing. Any improvement in technique or method during the course of the study will be evaluated and incorporated if significant. A quantitative cross flow will be reported.

II. DESCRIPTION

A variety of tests will be performed with the dual channel test section. Flow velocity and pressure drop information will be recorded at a number of flow rates. Data acquisition and reduction will be performed as in reference 1 and 2. In general this is a continuation of efforts reported in reference 2.

MASTER

A. Test Methods

The resistance method uses the proportionality between electrode resistance and tracer concentration to determine the cross flow. A DC recording at each cell in both channels for tracer injection in one channel will yield the tracer concentration change in each channel and therefore the cross flow.

The correlation method of cross flow determination postulates that the correlation coefficient is proportional to tracer concentration. A comparison of the correlation coefficients between the last electrode in the channel and all preceding electrodes will yield a quantity proportional to cross flow as a function of distance along the channel. The model for this method and a discussion of the proportionality between correlation coefficient and tracer concentration is given in the Analysis Section.

The model method uses a hydraulic resistance and pressure generator network. Measurements are made of flow velocity and pressure drop to determine the hydraulic resistances. The cross flow is then determined from the size of the resistors and pressure rises.

B. Test Section

A specially constructed dual channel test section is used for this test. This test section has been assembled to close tolerances with rigid quality control. Both pressure taps and conductivity cells are used for multiple parameter measurements. The test section is sketched on figure 1. The dimensions of the elements and test section are:

OD of cladding	=	0.512"
ID of cladding	=	0.455"
OD, fin to fin	=	0.644"
Fin width	=	0.042"
Fin height	=	0.066"
Tube thickness	=	0.028"

The tube has twelve spiral fins at a pitch of 90° per ft. The flow area is measured as part of the experiment.

C. Test Loop

The test is performed in the small (75 gpm) test loop in Building 049 (Santa Susana). This loop is diagrammed on figure 2. The unique features of this loop are that it has two separate inlet lines with control valves and flowmeters. These inlet lines connect to a split inlet section and then into separate channels of the dual channel test section. The inlet flow at each channel can be varied and a ΔP induced across the two channels. Tracer can be injected in either or both channels.

III. ANALYSIS

A. Derivation of Dual Channel Cross Flow

The variation of tracer concentration K in a flow stream is given by the continuity equation

$$-\partial K / \partial t = \vec{v} \cdot \nabla K$$

Expanding in differential form about a unit cube

$$\begin{aligned} -dx dy dz (\partial K / \partial t) &= v_x dy dz (\partial K / \partial x) dx \\ &+ v_y dx dz (\partial K / \partial y) dy + v_z dx dy (\partial K / \partial z) dz \end{aligned}$$

Note that $dx dy dz$ is a volume and $v_x dy dz$ is a volumetric flow rate.

Applying this equation to the dual channel (approximated by two separate axial and cross flow channels),

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and taking the volume integral over unit lengths of test section (ΔZ and ΔX).

$$-V (\partial K / \partial t) = Q_x (\partial K / \partial x) \Delta X + Q_z (\partial K / \partial z) \Delta Z$$

Using a finite difference expansion for $\partial K / \partial x = (K' - K) / \Delta X$ and considering only the steady-state variations

$$Q_z (dK(z)/dz) = Q_x / \Delta Z (K' - K)$$

Writing equations for each of the axial channels (assuming equal flows), one has

$$Q_z [dK_1(z)/dz] = Q_x / \Delta Z [K_2(z) - K_1(z)]$$

$$Q_z [dK_2(z)/dz] = Q_x / \Delta Z [K_1(z) - K_2(z)]$$

Using a normalized tracer concentration of

$$K_1(0) = 0.0$$

$$K_2(0) = 1.0$$

one has the solution

$$K_1(z) = \frac{1}{2} [1 - \exp(-2Q_x/Q_z \Delta Z) z]$$

$$K_2(z) = \frac{1}{2} [1 + \exp(-2Q_x/Q_z \Delta Z) z]$$

The above derivation can be expanded to a number of cross flow channels by adding additional terms and an equation for each channel.

B. Correlation Coefficient to Concentration Relation

The correlation coefficient is postulated to be proportional to the concentration. This postulate will be experimentally proven by comparing the resistivity results with the correlation results. A formal derivation of this postulate is being considered.

C. Nodal Model

An alternate approach to the mixing problem is to devise a network of equivalent hydraulic resistances and pressure generators. For this test section the network would be

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The resistors are determined from Darcy's formula

$$R = \frac{\Delta P}{V^2}$$

ΔP is measured by pressure taps and V is obtained from transit time measurements. R_c is the cross resistance divided by two. The pressure generator ΔP is the same as the axial ΔP per unit length. This nodal model lends itself to code calculation of the flow distribution

IV. EXPECTED RESULTS

A pilot estimate of the Q_x/Q_z ratio is obtained by assuming equal pressure in the axial and cross flow channels (assuming relatively low pitch) and ratioing the calculated diameters. That is

$$\Delta P = k f L Q^2 / A^2 d$$

$$\frac{\Delta P_x}{\Delta P_z} = \frac{f_x L_x Q_x^2 A_z^2 d_z}{f_z L_z Q_z^2 A_x^2 d_x} = 1.0$$

$$\left. \frac{Q_x}{Q_z} \right|_{ch} = \frac{A_x}{A_z} \left[\frac{d_x f_z}{d_z f_x} \right]^{\frac{1}{2}} \quad \text{per cross flow channel}$$

$$\frac{Q_x}{Q_z} \text{ per ft} = \frac{(\text{Fin pitch})(\# \text{ of fins})}{360^\circ} \left. \frac{Q_x}{Q_z} \right|_{ch}$$

or

$$\frac{Q_x}{Q_z} = \frac{3A_x}{A_z} \left[\frac{d_x f_z}{d_z f_x} \right]^{\frac{1}{2}} \quad \text{per ft}$$

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where*

Q_x = volumetric cross flow

Q_z = volumetric axial flow

A_x = cross flow area = 0.00755 in^2

A_z = axial flow area = 0.0861 in^2

d_x = cross channel equivalent diameter
= 0.1306 in

d_z = axial channel equivalent diameter
= 0.1739 in

f_x = cross channel friction coefficient
= 0.0052 at an Re of $56,000$

f_z = axial channel friction coefficient
= 0.0059 at an Re of $29,000$

The expected cross flow ratio for forced cross flow parallel to the fins and axial flow parallel to the axial channel is then

$$\frac{Q_x}{Q_z} = 0.243 \text{ per ft}$$

Another cross flow path exists which is perpendicular to the axial channel. This cross flow is caused by natural turbulent mixing and is quantitatively given by reference 6 as:

$$M_n = (2K_n \text{ Re}^{m-1} \rho \text{vc } d_z) / 0.577 (c + d)$$

where*

K_n = empirical constant = 1.07

m = empirical exponent = 0.68

ρ = density = $62.0 \text{ \#/ft}^3$

c = average gap = $0.0145''$

Re = channel Reynolds number = $29,000$

d = rod diameter = $0.644''$

$$M_n = 0.0294 \text{ \#/sec/ft}$$

The total expected cross flow ratio and quantitative cross flow is

$$Q_x/Q_z = 0.269$$

$$M = 0.298 \text{ \#/sec/ft}$$

*Numeric values are for the actual test section.

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A typical concentration change vs. channel length is plotted on figure 3.

V. PROCEDURE

A. Checkout

1. Set up and check out test loop and test loop instrumentation. Flows between 0 and 10 gpm should be possible in each test channel and all manometers should be indicating. Fill loop with fresh (non-salted) water.
2. Set up and calibrate data acquisition equipment. Balance amplifiers and calibrate tape recorder frequencies. Connect cells to signal conditioning circuitry.

B. Correlation Tests

1. Record conductivity cell variations for equal flows of 4, 6, 8 and 10 gpm in each channel. Inject salt in one channel only.
2. Repeat step 1 with salt injection in the adjacent channel.
3. Repeat step 1 with salt injection in both channels.

C. DC Resistance Measurements

1. Set signal conditioning and amplifiers on DC.
2. Record cell resistance variation for no injection and a flow rate of 8 gpm in each channel.
3. Record cell resistance variation for injection in one flow channel.
4. Record cell resistance variation for injection in adjacent flow channel.
5. Record cell resistance variation for injection in both flow channels.
6. Repeat steps 2 thru 5 at flow rates of 4, 6 and 10 gpm.
7. The tracer injection cycle for each test condition is 30 sec off, 30 sec on and 30 sec off.

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D. Hydraulic Model Recordings

1. Record conductivity cell variations and pressure drops for the following flows.

<u>Channel 1</u>	<u>Channel 2</u>
8 gpm	8 gpm
4 gpm	8 gpm
0 gpm	8 gpm
8 gpm	4 gpm
8 gpm	0 gpm

Inject salt in both channels.

E. Channel Area Measurements

1. Determine channel cross sectional area by measuring partial volumes of the test channel and dividing by the partial lengths.

F. Data Acquisition

1. The following quantities are recorded for each run.
 - a) Water temperature
 - b) FM-1 and FM-2 flow rates
 - c) Total and partial pressure drops
 - d) Conductivity cell signals

The pressure drops are measured by manometers, the flow rates by orifice flowmeters, and the temperature by a thermometer.

2. The correlation method employs a tape recorder, signal conditioner, and amplifiers as described in reference 2.
3. Two different sets of equipment were used in the resistance method. The first was the same as that used in the correlation method with the amplifiers set on DC. The resistance value is obtained thru a calibration of the signal conditioning circuit. The second set of equipment was a Hewlett Packard (Model DY-2010B) digital data acquisition system. An oscillator, constant current source, digital voltmeter and a digital printer make up the basic unit. The system produces an AC voltage that is proportional to resistance. Fourteen conductivity cells and a calibration channel were recorded at five channels per second and the data read out digitally. A diagram of the system used is shown in figure 4.

4. The model method uses the same data acquisition, namely, transit times and pressure drop measurements, as in the correlation method. However, an array of pressure drop measurements are taken axially up the channel and across the channel as in the following sketch.

As shown on figure 1 the pressure taps are located half way between the conductivity cells such that a pressure reading is taken at the mean velocity point.

G. Data Reduction

1. Correlation Method

Each set of data recorded on magnetic tape is cut into loops and analyzed. The data is electronically correlated and a comparison made of the correlation coefficients between the last electrode upstream and all preceding electrodes. The correlation coefficients are then plotted as a function of cell distance and the decay constants derived from the curves. A description of the electronic correlator is presented in reference 1.

2. Resistance Method

This method uses the proportionality between electrode resistance and tracer concentration to determine mixing ratio.

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The cell resistances are first corrected because of data system non-linearities. These non-linearities are due to known input impedances and internal shunt capacitance in the acquisition system. The equation for determining the corrected resistance is

$$R = (.88) \frac{(R_m)(75K)}{(75K - R_m)}$$

where R_m is the measured value. Resistance measurements are taken before and during tracer injection for all fourteen cells. Concentration of salt tracer is inversely proportional to resistance. The concentration change C is

$$\Delta C \propto 1/R_I - 1/R_O$$

The proportionality constant is removed by dividing the concentration change for single channel injection by the concentration change for injection in both channels. This manipulation also normalizes individual cell characteristics. At this point the data is a number of normalized concentration changes as a function of axial channel distance and have the appearance of figure 3. The data is then fitted (reference 5) with an exponential of the form

$$C/C_O = A + B \exp(-Cz)$$

From the derivation, the cross flow ratio is then

$$Q_x/Q_z = C/2$$

VI. RESULTS AND CONCLUSIONS

A. Data

The raw data and calculations are presented in Appendix I. Figures 5, 6 and 7 present typical data plots for the resistance method and figures 8 and 9 for the correlation method. The indicated points on these figures are the data and the curve is the least squares fit of the data. The dotted lines indicate the concentration variation due to spiraling effects. Table 1 presents the cross flow ratios for the resistance and correlation methods.

B. Data Analysis

Three particular problems with regard to the data are: 1) departure of the raw data from the theoretical normalization, 2) scatter in the data points, and 3) offset or dual value in the data.

The departure from the normalization can be caused by two things. These are: loop saturation effects, and variation in the amount of injection. The amount of departure from the normalization is indicated on figures 5, 6 and 7 by the zero value in the injected channel being greater than 1, and the convergent value of both injected and non-injected channel approaching a value other than 0.5. Ideally, each run would be performed with a clean loop; that is, a loop with water of high resistivity. However, this is impractical. Thus, as the water becomes saturated with salt solution there will be slight differences introduced into the conductivity change as more and more salt is added to the loop. Since there is static pressure changes in the loop at the point of salt injection and since the salt was injected by a manually operated pressure, the amount of pressure to the salt solution varied from run to run. This would cause a variation in the amount of salt injected and therefore in the value of the concentration change. This departure from the normalization does not effect the results.

Scatter in the data can be caused by pitch variations in the tubing fins, streaming and spiraling effects, area variation in the channel, gap variations and local unequal flow in the axial channels due to the area variations. The area variations were about $\pm 5\%$ about a mean value of 0.1945 in^2 . The actual values are given in Appendix I. The gap varied between 0 and 15 mils and had an average value of 4 mils. Streaming is known to exist in channels of this type (reference 6 and 7), but it is impossible to assign a quantitative value to this effect. The unequal flow in the axial channels was determined by the transit time correlation method to be about 10% with the higher flow in the channel with the even numbered cells.

An offset of dual value of the data is caused by deviation from ideal mixing, streaming and spiraling effects. Reference 7 has a diagram describing these effects. The dotted curves of figures 5, 6 and 7 indicate the spiraling effect for this experiment. The repetition distance of this effect is about 20 inches. The determination of the magnitude is not possible without additional data points. Therefore, the data will be analyzed by eliminating those channels where this effect is pronounced; namely, the odd-odd and even-even injection-recording channels.

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The average value of the cross flow ratio and cross flow is then

$$Q_x/Q_z = 0.294/\text{ft}$$

$$M = 0.326 \text{ \#/sec/ft}$$

The M value agrees well with the calculated value of the expected results (0.298 \#/sec/ft). The slight increase in the measured value is probably due to additional forced mixing caused by the varying channel area.

C. Error Analysis

The values of cross flow ratio and curve fit uncertainty used are:

Q_x/Q_z	σ in %	$\Delta(Q_x/Q_z)$
0.269	± 23.0	± 0.0619
0.324	38.4	0.1244
0.230	22.1	0.0508
0.265	38.0	0.1007
0.211	38.1	0.0804
0.468	22.6	0.1057

The average Q_x/Q_z ratio R is

$$\overline{Q_x/Q_z} = \sum_i R_i/n$$

The uncertainty is given by

$$\sigma_t^2 = (\partial R_1/\partial F)^2 \sigma_1^2 + (\partial R_2/\partial F)^2 \sigma_2^2 + \dots$$

The uncertainty expression for an average is

$$\begin{aligned}\sigma_t &= (\sum_i \sigma_i^2)^{1/2}/n \\ &= 0.0371 \text{ per ft} \\ &= 12.6\%\end{aligned}$$

D. Comparison of Methods

A comparison of the three methods for determining the cross flow showed that the most data was obtained by the resistance method; however, this data also contained the most scatter. The offset problem was the largest difficulty with this method. The efficiency of the method or the amount of acceptable data with

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respect to the total data obtained was about 80%. The correlation method yielded numbers which were closest to the mean value; this method was not plagued with the offset problem. Scatter in the data was less and the shape of the characteristic concentration change was closest to the theoretical; however, this method only had an acceptable data efficiency of about 50%. The correlation method, because it does not allow the use of negative slopes on the characteristic curve would not be acceptable for multi-channel work. Furthermore, the plots of the correlation coefficients from the injected channels (figures 8 and 9) indicate that end effects and eddy erosion are influencing the characteristic shape. This is shown on the plots as a slanted instead of a horizontal line for the uninjected channel. Measurements for the model method could not be obtained because most of the flow crossed over in the first four uninstrumented inches of the test section. Therefore, this method could not be properly evaluated. This method is, however, a very handy tool for obtaining experimental simulations of the test to be performed. This rapid cross flow indicates that all of the cross flow is not parallel to the fins but crossing the fins as well. This fin crossing cross flow could be caused by local pressure variations due to inequalities in the channel. This additional cross flow would explain the difference between the measured and expected value of cross flow.

E. Miscellaneous

An independent check was obtained on the flow rates or flowmeters in the small test loop of Building 049. This was obtained by the correlation method by obtaining transit times and from these transit times and knowledge of the area of the channel, determining the velocity and then the flow rate in the test section. In all cases this flow rate as measured by transit times was within $\pm 3\%$ of that indicated by the flowmeters.

The gap between the two elements in the test section varied with the length. The design objective was to have zero gap, however, small variations in test section dimensions, tube dimensions, tube non-straightness and thermal expansion caused a slight variation in the dual channel gap. A listing of the approximate gaps at each cell location for the channel at operating conditions is as follows:

<u>Cell #</u>	<u>Distance from Inlet</u>	<u>Gap</u>
1	4"	0.000"
2	10"	0.002"
3	16"	0.003"
4	22"	0.000"
5	28"	0.015"
6	34"	0.003"
7	40"	0.005"

This yields an average gap of four thousandths of an inch.

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ACKNOWLEDGMENTS

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ATOMICS INTERNATIONAL

A Division of North American Aviation, Inc.

NO. AI-CE-TDR-1038DATE May 20, 1966PAGE 17 OF 34TABLE ITABULATION OF MEASURED CROSS FLOW RATIOS

<u>Sample Number</u>	<u>Injection Channel</u>	<u>Measurement Channel</u>	<u>Flow</u>	<u>Q_x/Q_z</u>
RESISTANCE METHOD				
1	Odd	Even	6 gpm	0.269/ft
2	Even	Odd	6	0.324
3	Odd	Even	8	0.230
4	Even	Odd	8	0.265
5	Odd	Odd	6	0.500
6	Even	Even	6	0.718
7	Odd	Odd	8	0.223
8	Even	Even	8	0.641
9	Odd	Even	4	0.468
10	Even	Odd	4	0.211
11	Even	Even	4	2.28
12	Odd	Odd	4	1.63

CORRELATION METHOD

1	Odd	Even	6	0.402
2	Odd	Even	8	0.399

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FIG 2. SCHEMATIC DIAGRAM of HWOCR CROSS FLOW TEST SECTION
TEST LOOP

DIGITAL DATA ACQUISITION SYSTEM BLOCK DIAGRAM

FIGURE 4

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APPENDIX I

DATA AND CALCULATIONS

PREPARED BY: <i>LMF.</i>	ATOMICS INTERNATIONAL A DIVISION OF NORTH AMERICAN AVIATION, INC.	May 20, 1966
CHECKED BY:		PAGE NO. 29 OF 34
DATE: 3-21-66	HNOCR CROSS FLOW TEST	REPORT NO.
		MODEL NO.

HNOCR CROSS FLOW TEST DATA

3-18-66

Amb Temp: 76°F

"CREW"
 P. Petrul
 B. Cassidy
 E. Thompson
 T. Funakura

REF. #	Water Temp.	FLOW FM-1 "a" gpm	FLOW FM-2 "b" gpm	AP 3b-4b psi	AP 2a-2b psi	AP Overall 1a-7b psi
A	108	6.00	5.90	2.53	0.13	-
A	79	7.95	7.95	4.50	0.22	-
A	80	5.95	6.00	2.71	0.13	15.58
A	82	3.70	3.85	1.24	0.05	7.13
B	100	8.00	7.95	4.39	0.22	-
B	100	5.90	5.90	2.51	0.12	14.58
B	101	3.85	3.85	1.17	0.05	6.93
C	101	7.90	8.00	4.37	0.17	-
C	101	5.80	5.75	2.41	0.09	13.95
C	101	3.90	3.80	1.20	0.06	7.02

Ref. #: "A" = SALT INJECTION IN BOTH "a" & "b" CHANNELS
 "B" = SALT INJECTION IN CHANNEL "b" ONLY.
 "C" = SALT INJECTION IN CHANNEL "a" ONLY.

Date Ref: A.I. Notebook
 # 316101, page 316116

PREPARED BY: <i>T.M.F.</i>	ATOMIC INTERNATIONAL A DIVISION OF NORTH AMERICAN AVIATION, INC.	May 20, 1966
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		MODEL NO.

"CREW"
P. Petral
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HNOCR CROSS FLOW TEST DATA

3-22-66

Amb. Temp. = 70°F

Ref. #	Water Temp. °F	FLOW FM-1 "a" gpm.	FLOW FM-2 "b" gpm.	ΔP 1a-2a psi	ΔP 1a-1b psi	ΔP 1b-2b psi	ΔP 2a-3a psi	ΔP 2a-2b psi	ΔP 2b-3b psi	ΔP 3a-3b psi	ΔP 1a-7 OVERALL psi
A	102	8.0	8.0	3.89	0.35	4.30	5.70	0.22	5.20	0.55	26.81
B	102	8.0	8.0	3.89	0.35	4.32	5.72	0.22	5.20	0.55	26.68
C	104	0	7.9	0.81	0.11	1.04	1.56	0.10	1.47	0.16	7.40
C	104	7.9	0	0.97	0.27	0.85	1.51	0.11	1.38	0.11	7.06

Ref #: "A" = Salt injection through channel "a" only.

"B" = Salt injection through channel "b" only.

"C" = Salt injection through both channels "a" and "b".

AVERAGE FLOW AREA

ELECTRODE	Af SA. - IN.
1	0.2015
2	0.2026
3	0.1900
4	0.1845
5	0.1918
6	0.1932
7	0.1981
AVE.	0.1945

Note: VOLUMETRIC FLOW AREA MEASUREMENTS WERE MADE AT EACH ELECTRODE, APPROXIMATELY 2" ABOVE AND 2" BELOW EACH ELECTRODE. SEE SKETCH BELOW.

Data Ref: A.I. Notebook
316101, page #316118
316119.

(8 GPM)									(6 GPM)								
CH.	EVEN	ODD	BOTH	MEAN MS	Kv	$\bar{V}$ FPS	Φ GPM	FLOW GPM	CH.	EVEN	ODD	MEAN MS	Kv	$\bar{V}$ FPS	Φ GPM	FLOW GPM	
2-4	.690		.790						2-4	.910	1.35						
4-6	.720	.610	.720						4-6	.920	.770						
6-8	.540	.530	.540						6-8	.700	.700						
8-10	.520	.530	.500						8-10	.660	.660						
11-12	.517	.524	.562						10-12	.680	.680						
12-14	.663	.656	.628	20.76	.942	22.68	13.75		12-14	.870	.860	27.68	.920	16.61	10.07		
AVE.									AVE.								
X 32	19.45	18.24	19.93	19.20	.945	24.60	14.91	15.85	X 32	25.28	23.68	24.48	.931	19.01	11.53	11.95	
1-3		.720	.950						1-3	.590	1.05						
3-5		.570	.600						3-5	.930	.690						
5-7		.590	.650						5-7	.750	.770						
7-9	.310	.520	.410						7-9	.450	.650						
9-11	.567	.579	.697						9-11	.690	.770						
11-13	.556	.591	.453	17.05	.950	27.85	16.89		11-13	.760	.770	24.48	.931	19.02	11.53		
AVE.									AVE.								
X 32	15.30	19.04	20.06	18.14	.948	26.13	15.84	15.85	X 32	22.40	24.96	23.68	.934	21.11	12.80	11.95	
CH.																	
2-4	1.64																
4-6	1.37	1.17															
6-8	.93	1.05															
8-10	1.07	1.03															
10-12	1.06	1.03															
12-14	1.31	1.29		41.60	.873	10.49	6.36										
AVE.																	
X 32	39.36	35.52		37.44	.886	11.83	7.18	7.80									
1-3		1.33															
3-5		1.03															
5-7	1.04	1.18															
7-9	.95	1.01															
9-11	1.04	1.10															
11-13	1.16	1.15		36.96	.888	12.01	7.28										
AVE.																	
X 32	33.60	34.16		34.88	.898	12.86											

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(6 GPM)

(8 GPM)

RESISTIVITY METHOD

(4 GPM)

EVEN CH. INJ.			ODD CH. INJ.			BOTH CH.			EVEN CH.			ODD CH.			EVEN CH.			ODD CH.		
CELL	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T	CORR. COEFF.	T		
14-12	.77	.663	.86	.656	.63	.628	.75	.87	.85	.86	.48	1.31	.83	1.29						
14-10	.70	1.18	.74	1.18	.62	1.19	.68	1.55	.76	1.54	.46	2.37	.77	2.32						
14-8	.55	1.70	.64	1.71	.50	1.69	.57	2.21	.66	2.20	.37	3.44	.68	3.35						
14-6	.68	2.24	.62	2.24	.59	2.23	.68	2.91	.66	2.90	.42	4.37	.63	4.40						
14-4	.60	2.96	.47	2.85	.47	2.95	.56	3.83	.48	3.67	.31	5.74	.42	5.57						
14-2	.44	3.65	-	-	.31	3.74	.45	4.84	.09	5.02	.21	7.38	.10							
13-11	.62	.553	.87	.591	.54	.453	.56	.76	.82	.77	.37	1.16	.81	1.15						
13-9	.31	1.12	.79	1.17	.41	1.15	.40	1.45	.76	1.54	.29	2.20	.75	2.25						
13-7	.24	1.43	.71	1.69	.32	1.56	.25	1.90	.72	2.19	.23	3.15	.70	3.26						
13-5	.13	-	.70	2.28	.29	2.21	.18	2.65	.66	2.96	.16	4.19	.60	4.44						
13-3	-	-	.57	2.85	.26	2.81	.08	3.58	.60	3.65	.03		.51	5.47						
13-1	-	-	.38	3.57	.24	3.76		4.17	.42	4.70			.30	6.80						
← 8 GPM →									← 6 GPM →			← 4 GPM →								