9100B FLUID MECHANICS PROGRAM LISTING

75001 - CHEZY-MANNING EQUATION
Finds channel flow when channel is circular pipe and flowing full.

75003 - RECTANGULAR WEIR
Calculates the rate of fluid flow over a rectangular weir.

75004 - WATER FLOW IN PIPE
Calculates the loss factor (f) and the head loss for a pipe of specified dimensions with a known flow rate.

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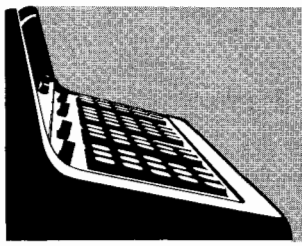


PART NO.
09100-75001

CHEZY - MANNING EQUATION

This program calculates the flow (Q) of an open channel.

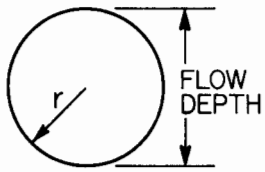
The basic equation for open channel flow with any designated flow depth in a container (pipe, etc.) with any cross-sectional area is the Chezy-Manning equation given below:

(1) $$Q = \frac{1.49\, AR^{2/3}\, S^{1/2}}{n}$$

where Q = Flow in ft.^{3}/sec.
A = Cross-sectional area of container in ft.^{2}
R = Hydraulic radius in ft.
S = Slope of pipe in feet/ft.
n = Roughness coefficient (dimensionless)

This program is specialized for open-channel flow in a circular pipe with flow depth designated at full.

Situation:



Then R = hydralic radius = $\frac{\text{area of flow cross-section}}{\text{wetted perimeter}} = \frac{\pi r^2}{2\pi r} = \frac{r}{2} = \frac{D}{4}$ (D = diameter of container)

substituting in equation (1) gives:

$$Q = 1.49 \left(\frac{\pi D^2}{4}\right)\left(\frac{D}{4}\right)^{2/3} \frac{S^{1/2}}{n}$$

$$= \frac{(1.49)(\pi/4)}{(4)^{2/3}} \frac{D^{8/3}\, S^{1/2}}{n} = \frac{.46441\, D^{8/3}\, S^{1/2}}{n}$$ (equation to be used)

Variables to be entered for flow calculation are D, S, n.

Reference: Elementary Fluid Mechanics, 3rd. edition, Feb., 1959.
by John K. Vennard
John Wiley & Sons, Inc.

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0 —— Z
0 —— Y
0 —— X

ENTER DATA: n → Z, D → Y, S → X

PRESS: CONTINUE

DISPLAY

Q —— Z
0 —— Y
0 —— X

EXAMPLE

Find Q_{FULL} in a circular pipe of diameter 18 in., if the slope is .001 feet/ft. and n = .015

Input: n = .015
D = 1.5 $\left(\frac{18''}{12''} = 1.5'\right)$
S = .001 ft./ft.

Answer: Q = 2.8866 $ft.^3/sec.$

PART NO. 09100-75001

Step		Key	Code	Display x	Display y	Display z	Storage f	Storage e	Storage d	Storage c	Storage b	Storage a
0	0	CLEAR	20									
	1	STOP	41	S	D	n	ENTER n, D, S					
	2	$\sqrt{x}$	76									
	3	ROLL ↓	31									
	4	$y \rightarrow ( )$	40									
	5	f	15									
	6	ln x	65									
	7	$x \rightleftarrows y$	30									
	8	8	10									
	9	×	36									
	a	3	03									
	b	÷	35									
	c	↓	25									
	d	e^x	74	CALCULATE Q								
1	0	×	36									
	1	f	15									
	2	÷	35									
	3	.	21									
	4	4	04									
	5	6	06									
	6	4	04									
	7	4	04									
	8	1	01									
	9	×	36									
	a	CLEAR x	37									
	b	↑	27									
	c	END	46	0	0	Q	DISPLAY					
	d											
	0											
	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	a											
	b											
	c											
	d											

Step	Key	Code	Display			Storage					
			x	y	z	f	e	d	c	b	a
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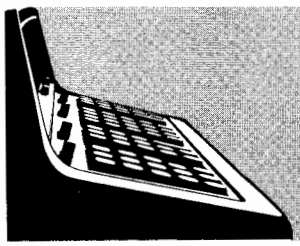
b											
c											
d											



PART NO.
09100-75003

RECTANGULAR WEIR

This program calculates the rate of fluid flow over a rectangular weir.

The following equations are used:

$$Q = 2/3 \; cb\sqrt{2g} \left[\left(H + \frac{V^2}{2g} \right)^{3/2} - \left(\frac{V^2}{2g} \right)^{3/2} \right]$$

where: Q = rate of fluid flow(ft.^{3}/sec.)
b = length of weir crest (ft.)
H = head on weir (ft.)
V = average velocity of fluid approach (ft./sec.)
c = correction factor

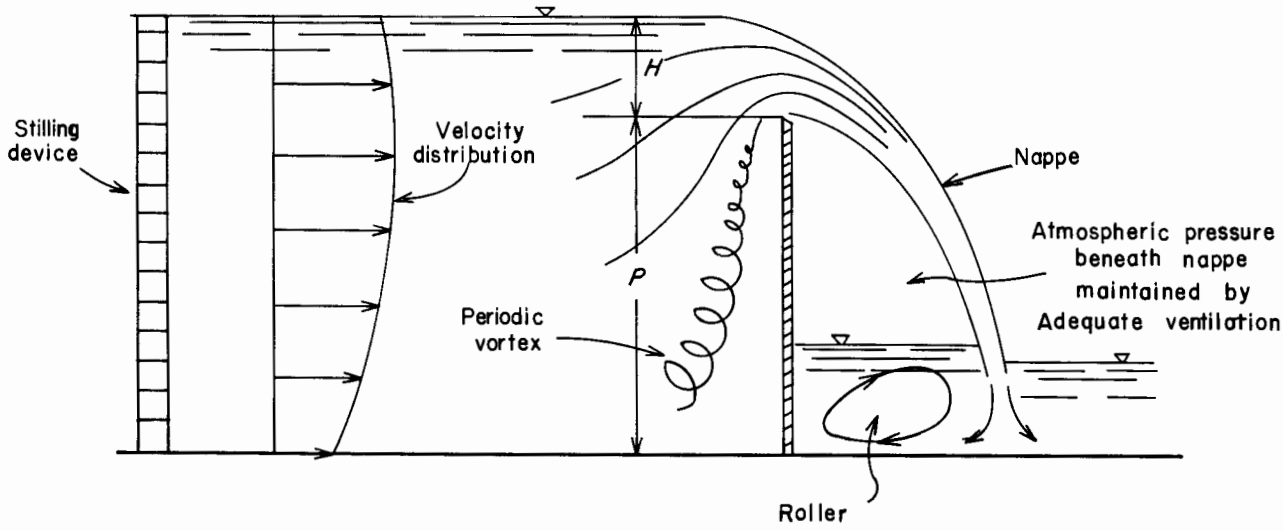
The coefficient (c) includes the effects of various phenomena, such as viscosity, turbulence, surface tension, non-uniform velocity, etc.

The program includes the ability to enter c as data, or to calculate c using Rehbock's equation, given below:

$$c = .605 + .08\, H/p + \frac{1}{305H}$$

where: p = the weir height

Diagram of a standard rectangular weir:



Reference: Elementary Fluid Mechanics - 3rd Edition
John K. Vennard
John Wiley & Sons, Inc.

USER INSTRUCTIONS

ENTER PROGRAM: (Starting Address is (0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

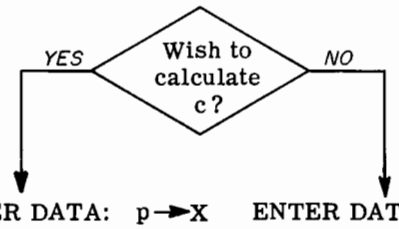
0 ——— Z
0 ——— Y
1 ——— X

ENTER DATA: V → Z, b → Y, H → X

PRESS: CONTINUE

DISPLAY

0 ——— Z
0 ——— Y
2 ——— X



ENTER DATA: p → X

PRESS: SET FLAG

PRESS: CONTINUE

DISPLAY

0 ——— Z
2 ——— Y
Q ——— X

(2 indicates that c was calculated)

ENTER DATA: c → X

PRESS: CONTINUE

DISPLAY

0 ——— Z
1 ——— Y
Q ——— X

(1 indicates that c was entered as data)

TO RESET PROBLEM:

EXAMPLES

(A)

Data: H = 1 ft.
V = 1 ft./sec.
b = 3 ft.
c = .6

(c entered as data)

Solution: Q = 9.8321 ft.^{3}/sec.

(B)

Data: H = 2 ft.
V = 1 ft./sec.
b = 6 ft.
p = 6.85 ft.

(c to be calculated)

Solution: Q = 57.8007 ft.^{3}/sec.

PART NO 09100-75003

Step		Key	Code	Display x	Display y	Display z	Storage f	e	d	c	b	a
0	0	CLEAR	20									
	1	1	01									
	2	STOP	41	H	b	V	ENTER DATA					
	3	ACC +	60									
	4	x→( )	23	STORE b AND H								
	5	C	16									
	6	↓	25									
	7	ROLL ↓	31									
	8	×	36									
	9	2	02									
	a	↑	27									
	b	3	03									
	c	2	02									
	d	·	21									
1	0	1	01									
	1	7	07									
	2	×	36									
	3	↓	25									
	4	÷	35									
	5	$\sqrt{x}$	76									
	6	↑	27									
	7	2	02									
	8	×	36									
	9	3	03									
	a	÷	35									
	b	E	12	CALCULATE $Q_p =$ $\frac{2}{3} b \sqrt{2g} \left[(H + \frac{V^2}{2g})^{3/2} - (\frac{V^2}{2g})^{3/2} \right]$								
	c	×	36									
	d	y→( )	40									
2	0	E	12									
	1	CLEAR x	37									
	2	ROLL ↑	22									
	3	ACC +	60									
	4	↑	27									
	5	$\sqrt{x}$	76									
	6	×	36									
	7	F	15									
	8	↑	27									
	9	$\sqrt{x}$	76									
	a	×	36									
	b	↓	25									
	c	x⇄y	30									
	d	−	34									

Step		Key	Code	Display x	Display y	Display z	Storage f	e	d	c	b	a
3	0	E	12									
	1	×	36									
	2	y→( )	40									
	3	d	17									
	4	CLEAR	20									
	5	2	02									
	6	STOP	41	C or P			ENTER DATA ; C or P					
	7	IF FLAG	43									
	8	4	04									
	9	6	06									
	a	↑	27									
	b	d	17									
	c	×	36									
	d	CLEAR x	37									
4	0	↑	27									
	1	1	01									
	2	ROLL ↑	22									
	3	GO TO( )( )	44									
	4	6	06									
	5	6	06									
	6	↑	27									
	7	3	03									
	8	0	00									
	9	5	05									
	a	↑	27									
	b	C	16									
	c	×	36									
	d	ROLL ↑	22									
5	0	÷	35									
	1	.	21									
	2	0	00									
	3	8	10									
	4	×	36									
	5	1	01									
	6	ROLL ↑	22									
	7	÷	35									
	8	.	21									
	9	6	06									
	a	0	00									
	b	5	05									
	c	+	33									
	d	CLEAR x	37									

STORE Q_P

BRANCH TO CALCULATE C IF P IS ENTERED AS DATA

CALCULATE Q FOR DATA ENTRY OF C

BRANCH TO DISPLAY Q

CALCULATE C IF P IS ENTERED AS DATA

FROM-4-5

Step	Key	Code	Display x	Display y	Display z	Storage f	e	d	c	b	a
6 0	ROLL ↓	31									
1	+	33									
2	d	17	CALCULATE Q FOR DATA ENTRY OF P (C CALCULATED)								
3	×	36									
4	2	02									
5	x⇄y	30									
6	END	46	Q	1 or 2		DISPLAY ; 1 or 2 INDICATES WHETHER C WAS ENTERED OR CALCULATED					
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Step	Key	Code	Display			Storage					
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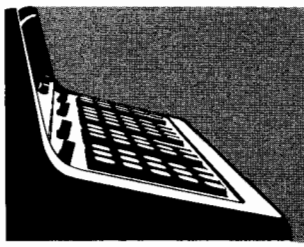

WATER FLOW IN PIPE

PART NO.
09100-75004

Given the roughness coefficient (ϵ), the diameter (d) of a pipe in inches, the rate of flow (Q) of water in gal./min. into the pipe, this program calculates the friction factor (f) and the head loss (h_f) in feet.

The equations used are the Colebrook equation

$$\frac{1}{\sqrt{f}} = -2 \log \left(\frac{2.51}{R_e \sqrt{f}} + \frac{12 \epsilon}{3.7 d} \right)$$

used to calculate f, and the Darcy-Weisback equation

$$h_f = f \left(\frac{L}{d} \right) \left(\frac{6 V^2}{g} \right)$$

where L = length of pipe in feet
and V = velocity in ft./sec.

R_e is Reynolds number where $R_e = \frac{Vd}{12\nu} = \frac{77 Q}{720 \pi \nu d}$

For water, $\nu = 1.40 \times 10^{-5}$ ft.^{2}/sec.

Therefore, $R_e = \frac{77 \times 10^5}{1008 \pi} \times \frac{Q}{d}$

Reference: Marks Standard Handbook for Mechanical Engineers
Seventh Edition
McGraw-Hill Book Company
1967

USER INSTRUCTIONS

ENTER PROGRAM (Starting Address is 0 - 0)

PRESS: GO TO (0) (0) [or END]

PRESS: CONTINUE

DISPLAY

0	Z
0	Y
1	X

ENTER DATA: Roughness Coefficient →Y,
Diameter →X

PRESS: CONTINUE

DISPLAY

0	Z
0	Y
2	X

ENTER DATA: Length →Y, Rate of Flow →X

PRESS: CONTINUE

DISPLAY

d	Z
Q	Y
f	X

PRESS: CONTINUE

DISPLAY

d	Z
Q	Y
h_f	X

To enter new data

EXAMPLE

Data:

d = 10 in.
ϵ = .00085
Q = 2000 gpm.
L = 500 ft.

Results:

f = .02035
h_f = 12.65377 ft.

PART NO 09100-75004

Step	Key	Code	Display x	Display y	Display z	Storage f	e	d	c	b	a	
0 0	CLEAR	20										
1	3	03										STORE 3, CLEAR AND DISPLAY 1 TO INDICATE FIRST ENTRY
2	x→( )	23										
3	a	13										
4	1	01										
5	STOP	41	d	ϵ	0							ENTER ROUGHNESS COEFFICIENT AND DIAMETER
6	÷	35										
7	x→( )	23										CALCULATE AND STORE RELATIVE ROUGHNESS (ϵ/d)
8	b	14										
9	y→( )	40										
a	c	16										
b	CLEAR	20										CLEAR AND DISPLAY 2 TO INDICATE SECOND ENTRY
c	2	02										
d	STOP	41	Q	L	0							ENTER LENGTH AND RATE OF FLOW
1 0	ACC +	60										STORE Q AND L
1	↑	27										
2	7	07										
3	7	07										
4	ENTER EXP	26										
5	6	06										
6	×	36										CALCULATE R_e
7	1	01										
8	0	00										
9	0	00										
a	8	10										
b	÷	35										
c	π	56										
d	÷	35										
2 0	b	14										
1	÷	35										
2	y→( )	40										
3	d	17										
4	2	02										
5	.	21										
6	5	05										
7	1	01										
8	↑	27										
9	d	17										
a	÷	35										
b	a	13										
c	×	36										CALCULATE $\Delta = 2\left\lvert \log\left(\frac{2.51}{R_e}\cdot\frac{1}{\sqrt{f}}+\frac{12}{3.7}\cdot\frac{\epsilon}{d}\right)\right\rvert^{-\frac{1}{\sqrt{f}}}$
d	c	16										

FROM 5-4

Step		Key	Code	Display x	Display y	Display z	Storage f	Storage e	Storage d	Storage c	Storage b	Storage a	
3	0	↑	27										
	1	1	01										
	2	2	02										
	3	×	36										
	4	3	03										
	5	·	21										
	6	7	07										
	7	÷	35										
	8	↓	25										
	9	+	33										
	a	↓	25										
	b	log x	75										
	c	↑	27										
	d	|y|	55										
4	0	2	02										
	1	×	36										
	2	a	13										
	3	−	34										
	4	2	02										CALCULATE $\Delta/2$
	5	÷	35										
	6	ENTER EXP	26										ENTER TOLERANCE, 10^{-3}
	7	3	03										
	8	CHG SIGN	32										
	9	IF x>y	53										BRANCH WHEN $\Delta/2$ < TOLERANCE
	a	5	05										
	b	5	05										
	c	a	13										ADD $\left(\frac{1}{\sqrt{f}}\right)_i + \frac{0_i}{2}$ AND STORE AS NEW ESTIMATE $\left(\frac{1}{\sqrt{f}}\right)_{i+1}$
	d	+	33										
5	0	y→( )	40										
	1	a	13										
	2	GO TO( )( )	44										BRANCH FOR $\frac{\Delta_{i+1}}{2}$ CALCULATION
	3	2	02										
	4	4	04										
	5	1	01										CALCULATE f
	6	↑	27										
	7	a	13										
	8	÷	35										
	9	↓	25										
	a	↑	27										
	b	×	36										
	c	y→( )	40										
	d	a	13										

Step		Key	Code	Display x	Display y	Display z	Storage f	Storage e	Storage d	Storage c	Storage b	Storage a
6	0	b	14									
	1	↑	27		RECALL AND POSITION DISPLAY							
	2	f	15									
	3	ROLL ↑	22									
	4	STOP	41	f	Q	d	DISPLAY f					
	5	d	17	RECALL R_e								
	6	↑	27									
	7	1	01									
	8	4	04									
	9	ENTER EXP	26									
	a	5	05									
	b	CHG SIGN	32									
	c	×	36									
	d	b	14	CALCULATE $V^2 = \left(\frac{\nu + R_e \times 12}{d}\right)^2$								
7	0	÷	35									
	1	1	01									
	2	2	02									
	3	×	36									
	4	↓	25									
	5	↑	27									
	6	×	36									
	7	b	14									
	8	÷	35									
	9	6	06									
	a	×	36									
	b	3	03									
	c	2	02									
	d	·	21									
8	0	2	02									
	1	÷	35									
	2	e	12	CALCULATE $h_f = \frac{f L V^2}{d g}$								
	3	×	36									
	4	a	13									
	5	×	36									
	6	b	14									
	7	↑	27									
	8	f	15		RECALL AND POSITION DISPLAY							
	9	ROLL ↑	22									
	a	END	46	h_f	Q	d	DISPLAY h_f					
	b											
	c											
	d											

Step	Key	Code	Display			Storage					
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