
CHAPTER 4

User's Guide

4.1. Introduction

It is assumed it is known how to use Hardy Cross method to calculate flow rates in pipe networks. MHcHp+ is an abbreviation that means Hardy Cross Method for the calculator HP49g+. MHcHp+ calculates flow rates in piping system balancing head losses in looped or branched pipe networks. It is considered loss coefficients k , pipe features, real and pseudo loops, pumps and the formula to calculate the resistance coefficient R , Hazen-Williams or Darcy-Weisbach. MHcHp+ was entirely developed into the calculator HP49g+ using the ROM 1.23 and was compiled in System RPL which gets the processing in faster. It was not used new addresses, so MHcHp+ can also run in HP49g and HP48gii.

MHcHp+ is a freeware. Therefore it can be used as many times as you want, only for educational purposes. It can be distributed only for free without any warranty of any kind and in its unmodified form.

Do not modify any file, name or grob into MHcHp.Dir, it might cause damages or information loss. In any case, use MHcHp+ as it is needed but at your own risk.

4.2. Acknowledgments

I would like to thank to many people who has helped me, directly or indirectly, to develop MHcHp+. Specially to my family and my friends for their support and my dear University for providing me the academic back up which has helped me in the development of this work.

To Eduardo M. Kalinowski and Carsten Dominik for their great reference manual "Programming in System RPL Second Edition".

To "adictoshp" from www.adictoshp.org which is a HP4X calculator Spanish page and to DOOCH for his advices for programming in ML.

To Eric Rechlin for supporting the best HP4X calculator program page www.hpcalc.org.

To God for guiding and taking care about me when I asked him for it.

And to Mr. Max Aguayo for correcting the english chapter of this thesis.

4.3. Installation

PC → Calculator → HOME	Copy MHcHp.Dir file into HOME
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Copy MHcHp.Dir file into HOME directory and that is all.

4.4. Main CHOOSE

HOME → MHcHp.Dir → MHcHp	Execute MHcHp
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Go into HOME directory and run MHcHp.Dir.

Execute MHcHp and it will be shown onto the screen a CHOOSE that will have nine options. As it is shown in figure 4.4.

1. New Project
2. Edit Project
3. Iteration
4. Results
5. H-W Coefficients
6. Wall Roughness
7. Results → STACK
8. About MHcHp
9. Quit

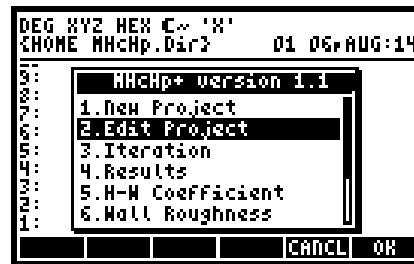


Figure 4.4 Main CHOOSE

4.5. New Project

HOME → MHCHP.Dir → MHCHP → 1.New Project	Choose option 1
---	-----------------

It is used arrow keys to access the item to select. In this case, it is selected item 1.New Project as it is shown in figure 4.5.

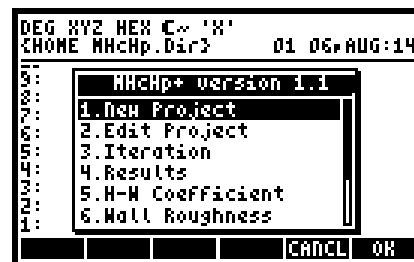


Figure 4.5

Take into consideration:

To do a new project it is required:

- To identify the problem.
- To select units system
- To know formula to calculate resistance coefficient R. ($h_f = R \cdot Q^x$)
- Number of pipes, at the most 45.
- Number of nodes (junctions), at the most 45. Do not consider the fixed-grade nodes because it will be assumed the number of loops as the difference between the number of pipes and the number of interior nodes, at least two
- Number of pumps, at the most 9.
- Density of fluid.
- Kinematic viscosity of fluid, it is used in Darcy-Weisbach.

- Gravitational acceleration.
- ΔQ accuracy, this will be a reference to finish the iteration.
- Pipe features (length, diameter, Hazen-Williams coefficient “C” or the wall roughness “e” and the absolute assumed flow rate. Do not forget to satisfy continuity.
- Loop features. They all must be positive in clockwise direction. Every pipe must belong to one or, at most, two loops.
- If there are pumps in the pipe network, to know in which pipe they are.

All these topics are explained in detail bellow.

4.5.1. Name of new project

HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project	Name new project
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It is displayed an Input Line onto the screen, as is shown in figure 4.5.1, where the name of the new project is requested. This will be the directory where variables are saved to iterate. They should not be algebraic signs or not allowed characters as +, -, ∂ , \int or " because they can not be purged using PGDIR.



Figure 4.5.1

4.5.2. System of units

HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project → SYSTEM	Choose system of units
---	------------------------

It is displayed onto the screen an Input Form, as is shown in figure 4.5.2, which asks you to choose system of units.

- International
- English

Figure 4.5.2

5.5.3 Main Data

<p>HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project → SYSTEM → MAIN DATA</p>	<p>Set main data of the pipe network</p>
---	--

It must be filled an Input Form, as figure 4.5.3a.

Figure 4.5.3a

Steps to follow

- Choose formula to calculate the resistance coefficient R ($h_f = R * Q^x$).
 - Hazen-Williams
 - Darcy-Weisbach
- Choose number of pipes, nodes (junctions) and pumps.
- If it is required, reset the values density of fluid, kinematic viscosity of fluid and/or gravitational acceleration.

- Choose ΔQ accuracy. Allowed values in this item are shown in figure 4.5.3b. It is used to compare it to the greatest ΔQ of loops or paths in each iteration. If ΔQ_{\max} is lesser than the chosen ΔQ accuracy, the iteration is concluded. It is recommended to use ΔQ accuracy equal to 0.001 due to there is an option, after iteration is concluded, asking if it is wanted to save final Qis as initial Qis. So if it is desired to increase the accuracy to iterate it again, it is not started with assumed flows.

Figure 4.5.3b

4.5.3. Enter pipes features

HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project → SYSTEM → MAIN DATA → Pipe i out of n	Set pipes features
--	--------------------

It is displayed an Input Form, as figure 4.5.4, it must be filled with every pipe data.

Figure 4.5.4

Step to follow

- Enter length (m o ft)
- Enter diameter (m o ft)
- Set Hazen-Williams coefficient “C” or wall roughness “e” depending on the formula chosen.

- Enter sum of all loss coefficients k along the pipe.
- Enter absolute assumed flow rate. **It must be satisfied continuity.**

4.5.4. Enter loops or path features

HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project → SYSTEM → MAIN DATA → Pipe i out of n → Loop i out of n	Enter loops or path features
--	------------------------------

It is shown an Input Form, as figure 4.5.5. It is required three data to fill it.

```

DEG XYZ HEX C~ 'X'
~Hp.Dir Eja3.Hc3 01 02.AUG:14
Loop 4. out of 5.
Pipes: { 8. -9. -10. 11. }
Shared: { 0. 0. 0. 1. }
ΔH: 0.
List of Pipes
EDIT [ ] [ ] [ ] [ ] CANCEL OK

```

Figure 4.5.5

- Pipes: it must be a list $\{ \}$ that contains the pipes belonging to the loop, each pipe must contain plus or minus sign depending on the assumed flow direction relative to the positive clockwise direction of the real or pseudo loop. Remember that all loops and pseudo loops must be positive in clockwise direction
- Shared: It must be a list $\{ \}$ with as many elements as “Pipes” have, where it must be entered which loop or path is shared with the corresponding pipe. In case that the pipe only belongs to one loop, it must be set 0 (zero).
- ΔH : For closed or real loops ΔH is equal to 0 (zero) and for path it must be entered the difference in magnitude of two fixed grade. So it is the final node piezometric head minus initial node piezometric head relative to the clockwise direction of the loop. To compute piezometric heads it must be used formula

$$H_N = \left(\frac{p}{\gamma} + z \right)_N$$

Example to enter loop data

It is known it could be difficult to understand. So, there is a simple example below to learn how to fill Input Lines as figure 4.5.5.1

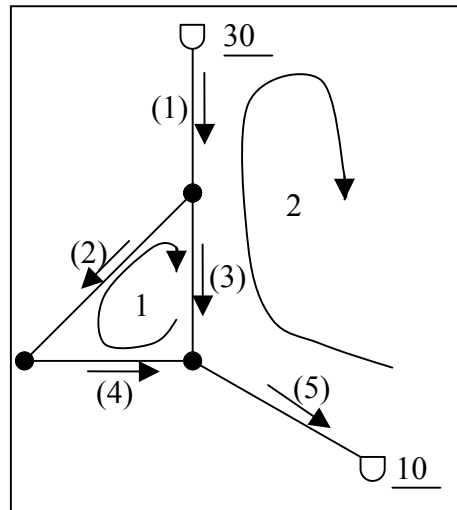


Figure 5.5.5.1

In the figure 5.5.1 is shown that there are 5 pipes, 3 interior nodes (junctions) and 2 fixed grade nodes.

It is had:

P; Number of pipes.

N; Number of interior nodes or junctions.

F; Number of fixed grade nodes.

L; Number of loops.

PL; Number of pseudo loops or paths

$$L + SL = P - N$$

$$SL = F - 1$$

In this case

$$L + SL = 2$$

Therefore

$$SL = 1 \text{ and } L = 1$$

So, data for loop 1

Pipes: {3 -4 -2}

Shared: {2 0 0}

ΔH : 0

and for loop 2

Pipes: {-5 -3 -1}

Shared: {0 1 0}

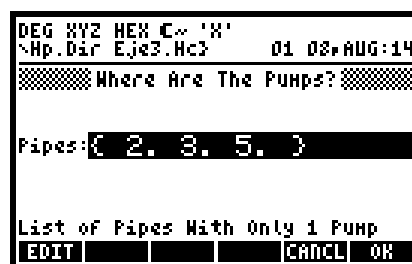
ΔH : 20

Note that pipe 3 is positive in loop 1 and negative in loop 2. This relation must be always respected.

4.5.5. List of pipes with only one pump

HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project → SYSTEM → MAIN DATA → Pipe i out of n → Loop i out of n → Where are the pumps?	Enter a list with pipes which have only one pump
--	---

It is displayed an Input Form onto the screen, as figure 4.5.6a.



```
DEG XYZ HEX C:\'X'
\Hp.Dir Ej83.Hc3 01 08 AUG:14
Where Are The Pumps?
Pipes: { 2, 3, 5, }
List of Pipes With Only 1 Pump
EDIT CANCEL OK
```

Figure 4.5.6a

Steps to follow

- Enter a list {} with as many elements as pumps in the pipe network. In case that piping system does not have any pump this step will be skipped.

Take into consideration

It must not be set the same pipe twice in this list, like {2 3 2}, because MHcHp+ will save pump 1 of the pipe 2, pump 2 of the pipe 3 and pump 3 will overwrite the pump 1. So, MHcHp+ will think that there are just two pumps in the piping system. In a pipe must have only one pump, in case that two or more pumps are connected in one pipe, the pipe must be separated. As it is shown in figure 4.5.6b.

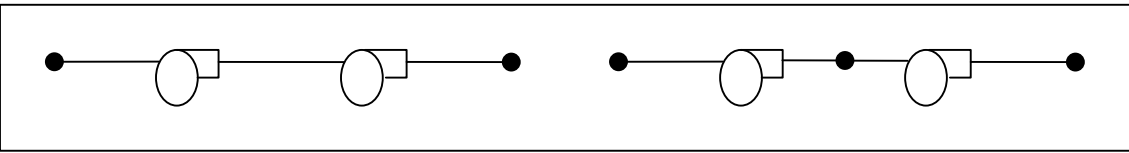


Figure 4.5.6b

When it is done, it is increased the number of nodes and pipes, but not the number of loops or pseudo loops of the piping system. Pumps supply energy to the piping system at the same direction of the flow. Hence, be very careful to interpret the results.

4.5.6. Enter pumps data

HOME → MHcHp.Dir → MHcHp → 1.New Project → Name of new project → SYSTEM → MAIN DATA → Pipe i out of n → Loop i out of n → Where are the pumps? → Pump curve	Choose equation to generate the pump curve
--	--

It is shown an Input Form as figure 4.5.7.

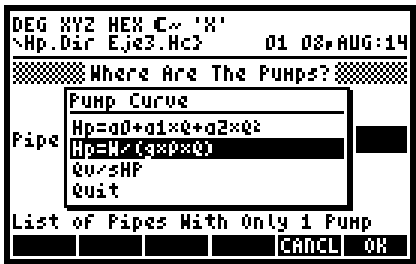


Figure 4.5.7

To choose any of these options, it must be known the pump data to generate the pump head-discharge curve.

To select

- $H_p = a_0 + a_1 \cdot Q + a_2 \cdot Q^2$: It must be known the constants a_0 , a_1 and a_2 to set.
- $H_p = W / (g \cdot \rho \cdot Q)$: In this option it is assumed useful power as a constant and it is asked for it. Units are set depending on the system of units chosen:

International System: W

English System: $\frac{lb - ft}{s}$

- Q_v / sHP : If it is chosen this option it is needed to know three data points from a specific pump curve. MHcHp+ will resolve the three resulting equation and will find the coefficients a_0 , a_1 and a_2 .

Take into consideration

If it is pressed CANCEL or ON in any MHcHp+'s CHOOSE or Input Form, MHcHp+ will not be able to iterate. So it must be pressed ENTER or OK as many times as MHcHp+ needs it.

To find the main CHOOSE, it is not needed to perform UPDIR, just it is must be pressed left-shift and CUSTOM.

4.6. Edit Project

HOME → MHcHp.Dir → MHcHp → 2.Edit Project	Choose option 2.
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It is used arrow keys to access the item 2.Edit Project as it is shown in figure 4.6a.

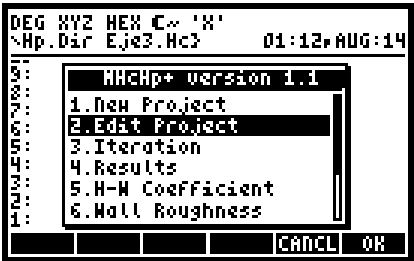


Figure 4.6a

It is displayed a CHOOSE onto the screen, as is shown in figure 4.6b, where the name project to edit must be selected. Its end must be Hc.

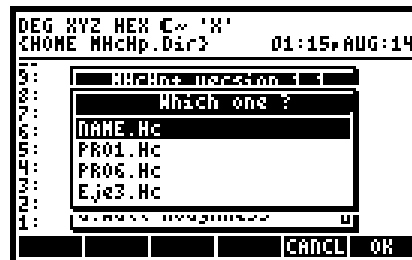


Figure 4.6b

Then, steps 4.5.2, 4.5.3, 4.5.4 and 4.5.5 are repeated. Besides, if there is any pump in the pipe network, also steps 4.5.6 and 4.5.7 are repeated. But now, Input Forms show real instead default data that it is set before.

Take into consideration:

When this option is chosen it must be considered that it is not able to iterate if it is pressed ON or the CANCEL while it is entered data. Because If it is added one or more pumps and it is exited from MHcHp+ without new pumps data, MHcHp+ will try to iterate, will not find them and it will be displayed onto the screen "Try To Recover Memory". Do not purge or modify any file.

4.7. Iteration

HOME → MHcHp.Dir → MHcHp → 3.Iteration	Choose option 3.
---	------------------

It is shown onto the screen a CHOOSE, Use arrow keys to select option 3.Iteration, as figure 4.7a. It is allowed to perform this option only if option 4.5 or 4.6 is finished as it is explained in considerations of 4.6.

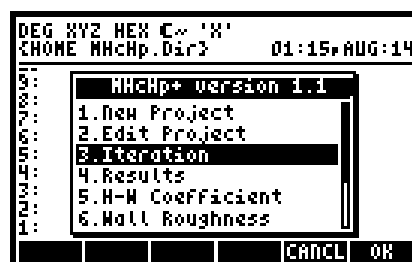


Figure 4.7a

While MHcHp is iterating, a waiting GROB is displayed onto the screen, as figure 4.7b, which shows the number of the iteration and ΔQ_{\max} (the greatest ΔQ of every loop or path). This is compared to ΔQ accuracy to know when to finish the iteration.



Figure 4.7b

If ΔQ_{\max} is not approaching to zero, iteration can be stopped to check data.

Possible mistakes could be:

- ΔH
- A pipe is missing or not included in a loop.
- List of pipes, “Pipes”
- List of “Shared” in loops.

So, you must be careful to enter data because if there are data mistakes, MHcHp+ could iterate and get results but they will be wrong. When MHcHp+ concludes to iterate, it is asked “save as initial Q?” (assumed Q_i), as it is shown in figure 4.4.3c. This option is very helpful if it is needed a high accuracy because editing the project, ΔQ accuracy can be increased and to iterate again. MHcHp+ will start to compute with closer to “reality” flows.

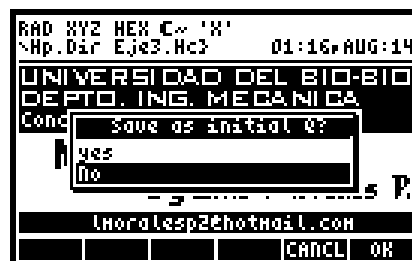


Figure 4.4.3c

Remember, it is not needed to perform UPDIR to find the main CHOOSE, just it must be pressed left-shift and CUSTOM.

4.8. Results

HOME → MHcHp.Dir → MHcHp → 4.Results	Choose option 4.
--------------------------------------	------------------

Use arrow keys to select item 4.Results, as it is shown in figure 4.8a. If iteration is correctly ended, this option can be chosen.

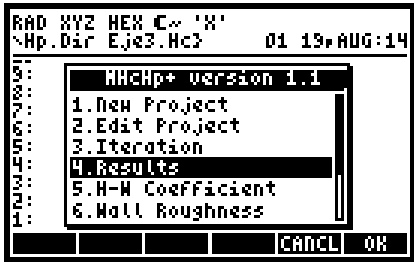


Figure 4.8a

When this option is chosen, a STRING is shown on the screen, as figure 4.8b, with the following data.

- Name
- Date
- Starting and end time
- System
- Formula
- etc.

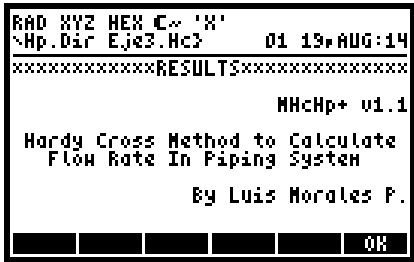


Figure 4.8b

Like it is shown bellow:

*****RESULTS*****

MHcHp+ v1.1

Hardy Cross Method to Calculate
Flow Rate In Piping System

By Luis Morales P.

* Name of Project: Eje3.Hc

* Date: 08/14/05

* Starting Time: 01:37:11P

* End Time: 01:40:07P

* System: International

* Formula: Darcy-Weisbach

* Number of Pipes: 16

* Number of Nodes: 11

* ΔQ Accuracy: 0.001

* Iterations: 11.

Loop 1.

Pipe

Flow m³/s

2.

459.666E-3

13.

142.638E-3

14.

-74.9720E-3

11.

-237.806E-3

12.

-363.724E-3

Loop 2.

Pipe

Flow m³/s

3.

177.028E-3

5.

83.6379E-3

16.

7.38998E-3

15.

-77.6100E-3

13.

-142.638E-3

Loop 3.

Pipe

Flow m³/s

6.

-23.7521E-3

7.

-123.752E-3

14.

74.9720E-3

15.

77.6100E-3

16.

-7.38998E-3

Loop 4.

Pipe

Flow m³/s

8.

39.0823E-3

9.

-15.9177E-3

10.

-70.9177E-3

11.

237.806E-3

Loop 5.

Pipe

Flow m³/s

1.

-823.391E-3

2.

-459.666E-3

3.

-177.028E-3

4.

-93.3905E-3

ID MHcHp: 75231.-Ö

If it is wanted to ask something about MHcHp+, it can be sent a e-mail the author to lmoralesp2@hotmail.com attaching the ID of a result, as it is shown at the end of STRING above.

4.9. H-W Coefficient

HOME → MHcHp.Dir → MHcHp → 5.H-W Coefficient	Choose option 5.
---	------------------

When MHcHp is run, it used arrow keys to select item 5.H-W Coefficient, as figure 4.9a.

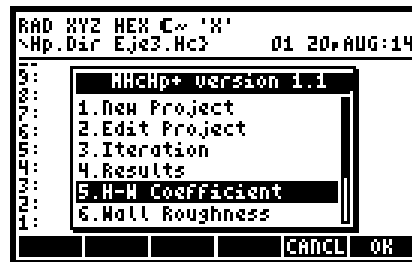


Figure 4.9a

It is displayed a STRING with nominal values of the Hazen-Williams coefficient “C” of some type of pipes. As it is shown in figure 4.9b.

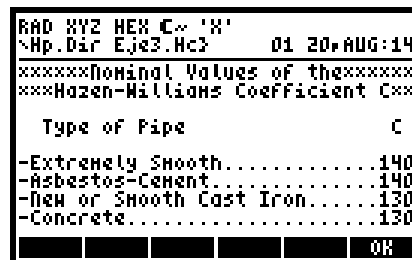


Figure 4.9b

4.10. Wall Roughness

HOME → MHcHp.Dir → MHcHp → 6.Wall Roughness	Choose option 6.
---	------------------

After MHcHp is performed, it is used arrow keys to choose option 6.Wall Roughness, as figure 4.10a.

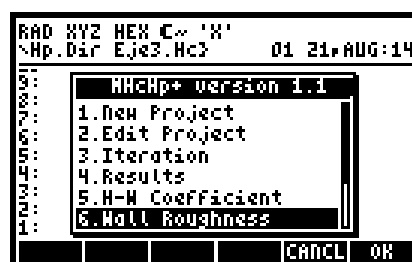


Figure 4.10a

It is shown a STRING with typical wall roughness for commercial conduits which can be used for Darcy-Weisbach formula. As it is shown in figure 4.10b

```

RAD XYZ HEX C~ 'X'
~Hp.Dir Eje3.Hc3 01 21.AUG:14
**Typical Wall Roughness Values**
*****For Commercial Conduits*****

Material      e
-Riveted Steel.....~0.01 Ft
                  ~0.003 M
-Concrete.....~0.001-0.01 Ft
                  ~0.0003-0.003 M

```

Figure 4.10b

4.11. Results → STACK

HOME → MHcHp.Dir → MHcHp → 7.Results → STACK	Choose option 7.
---	------------------

To perform this option, it is used arrow keys after to run MHcHp, as figure 4.11.

```

RAD XYZ HEX C~ 'X'
~Hp.Dir Eje3.Hc3 01 21.AUG:14
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Figure 4.11

If iteration is concluded, results are put onto the stack to do whatever it is wanted.

4.12. About MHcHp+

HOME → MHcHp.Dir → MHcHp → 8.About MHcHp+	Choose option 8.
--	------------------

MHcHp must be performed and it is used arrow keys to select item 8.About MHcHp+, as figure 4.12a shows.

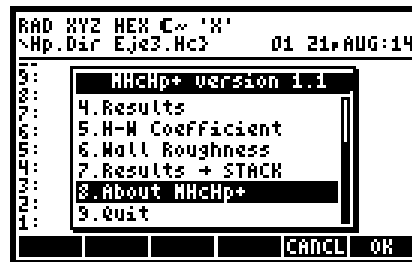


Figure 4.12a

It is shown a GROB with a STRING moving on the menu position of the screen.
As figure 4.12b



Figure 4.12b

4.13. Quit

HOME → MHcHp.Dir → MHcHp → 9.Quit	Choose option 9.
-----------------------------------	------------------

It is used arrow keys to execute option 9.Quit, as figure 4.13. Choosing this option, it is abandoned the main CHOOSE of MHcHp+, Also it can be quit pressing ON or CANCEL.



Figure 4.13