K-Fire Sprinkler Hydraulic Calculation Verification Report

— Comparison with PIPENET —

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Korea Fire Research Institute

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1. Summary

1.1 Purpose

This report was prepared to verify the calculation results of K-Fire, a sprinkler hydraulic calculation program. The reference program is PIPENET, a hydraulic calculation program that is widely used worldwide and is the most widely used in Korea. The results of the two programs were compared under identical input conditions.

1.2 Verification Conditions

Item	Description
Calculation method	Demand Mode based on 1.0 bar at the most remote head (design flow calculation)
Friction loss formula	Hazen-Williams, C = 120
Pipe	KSD 3507 (same internal diameters applied)
Head	K = 80 (L/min/bar^½), minimum discharge pressure 1 bar at the most remote head
Fitting losses	Equivalent length of each pipe calculated by K-Fire per NFPA 13, entered identically in PIPENET
Verification networks	Tree (30 heads), grid (30 of 112 heads active)

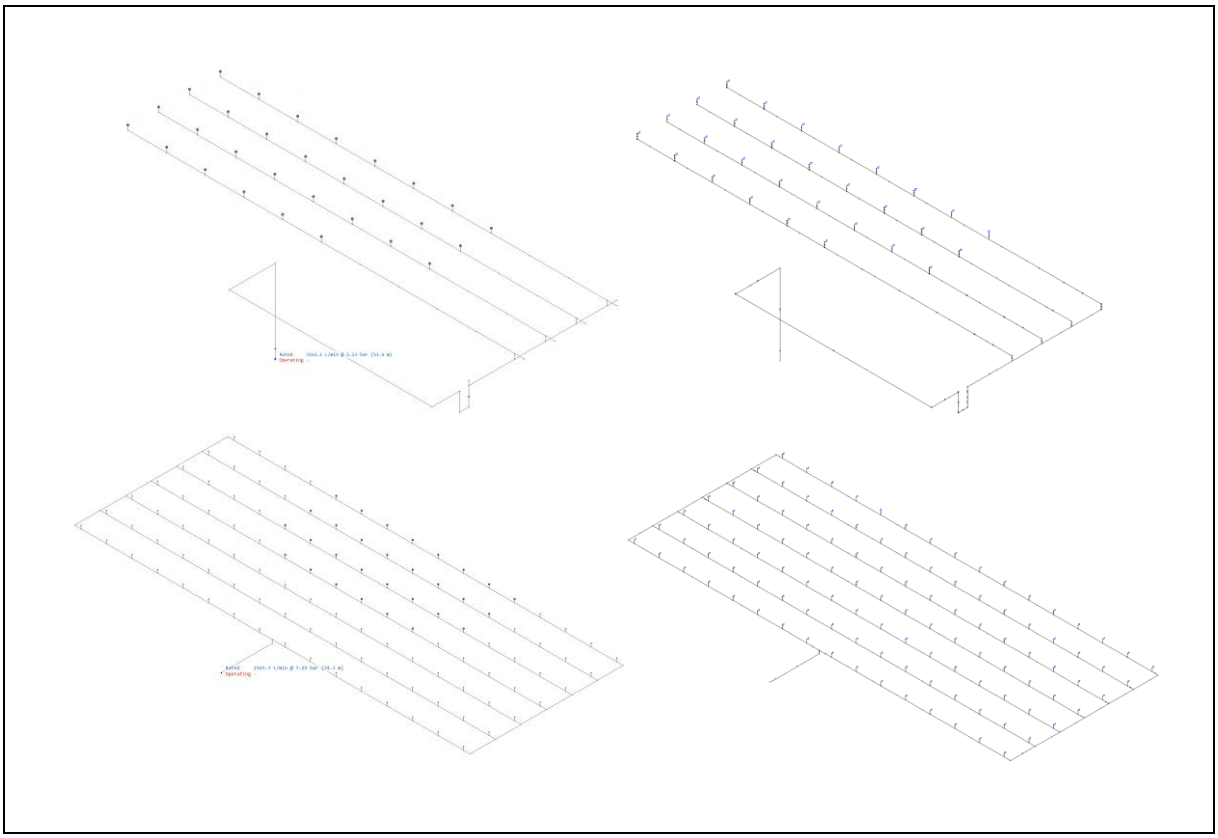


Figure 1. Verification networks (top: tree, bottom: grid / left: K-Fire, right: PIPENET)

1.3 Acceptance Criteria

NFPA 13 requires hydraulic calculations to balance pressures at junction points within 0.03 bar. This value is not intended for comparing the results of two programs, but it was used as a reference to set stricter criteria.

Comparison item	Acceptance criterion
Head pressure	Within ±0.01 bar
Head discharge, pipe flow	Within ±0.5%
Node pressure (incl. supply point)	Within ±1%

1.4 Comparison Results

Tree network (30 heads)

Item	K-Fire	PIPENET	Difference	Result
Design flow (L/min)	**3,162.1**	**3,161.0**	−0.03%	Pass
Supply pressure (bar)	**5.234**	**5.223**	−0.011 bar (−0.21%)	Pass
Most remote head	**N523**	**N523**	Match	Pass
Max. head pressure difference			0.003 bar	Pass
Max. head discharge difference			0.08%	Pass
Max. pipe flow difference			0.10%	Pass
Max. node pressure difference			0.25%	Pass
Flow direction			All pipes match	Pass

Grid network (30 of 112 heads active, 6 loops)

Item	K-Fire	PIPENET	Difference	Result
Design flow (L/min)	**2,565.3**	**2,564.6**	−0.03%	Pass
Supply pressure (bar)	**7.286**	**7.257**	−0.029 bar (−0.39%)	Pass
Most remote head	**N486**	**N486**	Match	Pass
Max. head pressure difference			0.001 bar	Pass
Max. head discharge difference			0.05%	Pass
Max. pipe flow difference			0.05%	Pass
Max. node pressure difference			0.39%	Pass
Flow direction			All pipes match	Pass

1.5 Source of Differences

Both programs use the Hazen-Williams formula for friction loss. K-Fire uses the precise Hazen-Williams formula (flow exponent 1.852, diameter exponent 4.871) of the EPANET solver built into the program. The very small differences between the two programs come from the number of significant digits in the coefficient and exponents of the formula and from the precision of unit conversion. The friction loss difference for a single pipe is −0.2 to +0.7%, and K-Fire calculates slightly higher losses at higher flows. K-Fire calculated the pump pressure 0.011–0.029 bar higher, which is practically insignificant.

1.6 Conclusions

1. Under identical input conditions, the results of K-Fire and PIPENET met the acceptance criteria for all items. The maximum head pressure difference is 0.003 bar and the maximum flow difference is 0.1%.
2. The differences between the two programs are at the level of the significant digits of the Hazen-Williams coefficient and exponents and of unit conversion precision. In both networks K-Fire calculated the supply pressure very slightly higher, by an insignificant amount.
3. In addition, because K-Fire calculates fitting equivalent lengths automatically from the drawing, the input errors that can occur when the schematic and the calculation input are kept separate cannot occur by design.

2. Programs and Conditions

2.1 Programs Compared

Category	K-Fire	PIPENET VISION
Developer	Korea Fire Research Institute	Sunrise Systems (UK)
Solver	EPANET 2.2 (built in)	Proprietary solver
Friction loss formula	Hazen-Williams	Hazen-Williams
Loop analysis	Supported	Supported

PIPENET is widely used worldwide and is the most widely used sprinkler hydraulic calculation program in Korea. It was therefore chosen as the reference.

K-Fire has EPANET built in as its hydraulic solver. EPANET is a pipe network analysis program developed and released by the U.S. Environmental Protection Agency (EPA), and it is a de facto standard for water distribution network analysis. K-Fire uses the precise Hazen-Williams formula of this solver as is.

2.2 Calculation Conditions

The following conditions were applied identically to both programs.

Item	Condition applied
Calculation method	Find the design flow and supply pressure that provide 1.0 bar at the most remote head
Friction loss formula	Hazen-Williams, C = 120
Pipe	KSD 3507. The same internal diameter for each nominal size was entered in both programs (25A 27.5 mm, 50A 53.2 mm, etc.)
Head	K = 80 (L/min/bar^½), minimum discharge pressure 1.0 bar
Fitting losses	Equivalent length per pipe. The values calculated by K-Fire per NFPA 13 were entered identically in PIPENET
Water density	1,000 kg/m³
Velocity head	Not included (both programs)
Convergence criterion	PIPENET: convergence tolerance 1×10^{-4}. K-Fire: pressure within 0.005 m

The fitting losses were entered with the same values for the following reason. The purpose of this comparison is to confirm that **the calculation engines produce the same answer**. If each program also calculated its own fitting losses, it would be impossible to tell whether a difference came from the engine or from the fitting calculation. The fitting losses were therefore set to the values calculated by K-Fire, and only the engines were compared. K-Fire's fitting calculation follows the NFPA 13 rules.

2.3 Comparison of Input Methods

The two programs use different methods to enter a pipe network.

Category	K-Fire	PIPENET
Pipe drawing	3D drawing of the actual geometry	Schematic drawing (not used in the calculation)
Pipe length	Entered by the user	Entered by the user
Elevation (height difference)	Calculated automatically when the pipe length is entered	Entered separately for each pipe
Fittings (equivalent length)	Calculated automatically (per NFPA 13)	Fitting type and quantity entered for each pipe

In both programs the user enters the pipe sizes and lengths. PIPENET, however, requires the length and the elevation change to be entered separately for each pipe. Because the drawing is not used in the calculation, the calculation proceeds even if the drawing differs from the actual piping. The user must separately check that the input values match the actual piping.

In K-Fire, the direction and length in which each pipe is drawn are the calculation input. Elevation changes are calculated automatically from the drawing direction, and fittings are determined automatically from the drawing geometry. There is no room for the drawing and the calculation to disagree.

3. Verification Method

3.1 Creating Identical Input

1. **K-Fire demand calculation:** Calculate with 1.0 bar at the most remote head and finalize the fitting equivalent length of each pipe.
2. **Transferring the network:** Transfer the nodes and pipes to PIPENET with the same numbers as in K-Fire, so that the results of the two programs can be compared directly number by number. The 6 dead-end pipes (zero flow) in the tree drawing were excluded in accordance with PIPENET input rules.
3. **Transferring pipe data:** Transfer the length, nominal size, elevation change and C-factor of each pipe as is. Internal diameters are entered in the PIPENET pipe library with the same values as in K-Fire.
4. **Transferring equivalent lengths:** Enter the equivalent lengths calculated by K-Fire in PIPENET's "user-specified equivalent length" field, so that PIPENET does not perform its own fitting calculation.
5. **Transferring heads:** Active heads are entered as nozzles with K = 80 and a minimum discharge pressure of 1.0 bar.

3.2 Checking Fitting Equivalent Lengths

The same equivalent lengths were entered in K-Fire and PIPENET. K-Fire's fitting calculation follows the NFPA 13 rules.

The NFPA 13 rules are as follows.

- At a tee, the equivalent length is applied only where the flow turns 90° (branch), and not where it passes straight through (run).
- Equivalent lengths are taken from the Schedule 40 table and adjusted by the actual internal diameter ratio and the C-factor ratio.

Every branch point in the two drawings was reclassified by its coordinates and flow direction and checked against K-Fire's results.

Branch point type	Tree network	Grid network	K-Fire result
90° branch	35	38	Tee (branch) equivalent length applied at all
Straight run	29	82	Not applied at any
Agreement	64/64 (100%)	120/120 (100%)	

3.3 Acceptance Criteria

NFPA 13 requires hydraulic calculations to balance pressures at junction points within 0.03 bar. Using this value as a reference, this verification set stricter criteria for comparing the results of the two programs.

Comparison item	Acceptance criterion
Head pressure	Within ±0.01 bar
Head discharge, pipe flow	Within ±0.5%
Node pressure (incl. supply point)	Within ±1%

3.4 Comparison Items

- Design flow and supply pressure
- Location of the most remote head
- Pressure and discharge of all active heads
- Flow, velocity and flow direction in all pipes
- Pressure at all nodes

4. Case 1: Tree Network

4.1 Network Overview

A branched (tree) network that rises from the pump through a riser and divides via a cross main into 4 branch lines. All 30 active heads are on the same floor.

Item	Value
Number of pipes	93
Number of nodes	94
Head	30 (all active)
Total pipe length	249.52 m
Pipe sizes	25A, 32A, 40A, 50A, 65A, 100A, 125A, 150A
Supply point (pump) elevation	16 m
Head elevation	26 m
Valves	1 alarm valve, 1 swing check valve

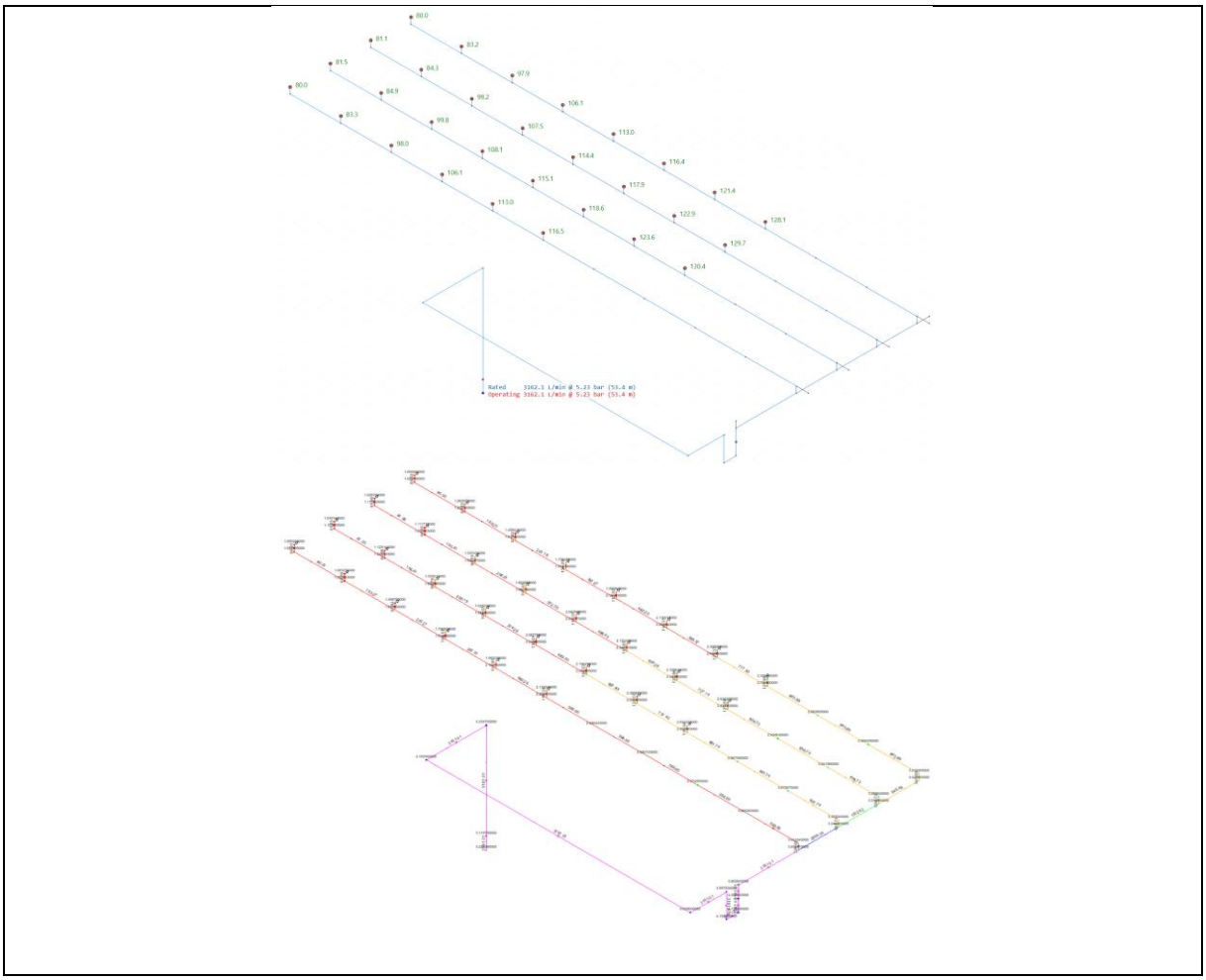


Figure 2. Tree network (left: K-Fire, right: PIPENET)

4.2 Input Consistency Check

The input actually read by PIPENET was extracted again from the PIPENET output and checked against the K-Fire input.

Item	K-Fire	PIPENET	Remarks
Number of pipes	93	87	6 dead-end pipes excluded (zero flow)
Number of active heads	30	30	Same (K=80)
25A total length (m)	48.60	48.60	Same
32A total length (m)	16.80	16.80	Same
40A total length (m)	16.80	16.80	Same
50A total length (m)	63.50	63.50	Same
65A total length (m)	42.64	42.64	Same
100A total length (m)	6.68	6.68	Same
125A total length (m)	5.00	5.00	Same
150A total length (m)	44.00	44.00	Same
Total equivalent length (m)	153.395	153.394	Same (difference in printed digits)
Pipes with length/size/C mismatch		0	87 pipes checked one by one

The excluded dead-end pipes are P421, P457, P493, P529, P646 and P659 (25A, 0.5–1.0 m long). The length totals above exclude these 6 pipes.

4.3 Results Summary

Item	K-Fire	PIPENET	Difference	Result
Design flow (L/min)	**3,162.1**	**3,161.0**	−0.03%	Pass
Supply pressure (bar)	**5.234**	**5.223**	−0.011 bar (−0.21%)	Pass
Most remote head	**N523 (1.000 bar)**	**N523 (1.000 bar)**	Match	Pass
Max. head pressure difference			0.003 bar	Pass
Max. head discharge difference			0.08%	Pass
Max. pipe flow difference			0.10%	Pass
Max. node pressure difference			0.25%	Pass
Flow direction			All pipes match	Pass

4.4 Results by Head

The pressures and discharges of the 30 active heads are listed in order of increasing pressure.

No	Head	Pressure K-Fire (bar)	Pressure PIPENET (bar)	Difference (bar)	Discharge K-Fire (L/min)	Discharge PIPENET (L/min)	Difference (%)
1	N523	0.9996	1.0000	+0.0004	79.99	80.00	+0.007
2	N599	1.0001	1.0003	+0.0001	80.02	80.01	−0.006
3	N559	1.0263	1.0267	+0.0004	81.06	81.06	+0.005
4	N579	1.0388	1.0391	+0.0004	81.55	81.55	+0.004
5	N517	1.0825	1.0830	+0.0005	83.25	83.25	+0.008
6	N594	1.0831	1.0833	+0.0002	83.27	83.26	−0.006
7	N554	1.1113	1.1117	+0.0004	84.35	84.35	+0.005
8	N574	1.1248	1.1251	+0.0004	84.85	84.86	+0.004
9	N521	1.4984	1.4984	+0.0001	97.94	97.93	−0.012
10	N600	1.4991	1.4988	−0.0003	97.96	97.94	−0.025
11	N560	1.5374	1.5374	0.0000	99.21	99.19	−0.014
12	N580	1.5557	1.5556	−0.0001	99.79	99.78	−0.016
13	N526	1.7589	1.7585	−0.0004	106.11	106.09	−0.025
14	N585	1.7598	1.7589	−0.0009	106.14	106.10	−0.038
15	N545	1.8044	1.8039	−0.0005	107.48	107.45	−0.027
16	N565	1.8256	1.8250	−0.0006	108.11	108.08	−0.029
17	N514	1.9938	1.9928	−0.0010	112.98	112.93	−0.037
18	N592	1.9948	1.9933	−0.0015	113.01	112.95	−0.050
19	N552	2.0450	2.0439	−0.0011	114.42	114.37	−0.040
20	N572	2.0689	2.0678	−0.0012	115.09	115.04	−0.042
21	N528	2.1173	2.1160	−0.0013	116.42	116.37	−0.044
22	N591	2.1184	2.1165	−0.0019	116.45	116.39	−0.057
23	N551	2.1716	2.1701	−0.0015	117.91	117.85	−0.047
24	N571	2.1968	2.1953	−0.0016	118.59	118.53	−0.049
25	N530	2.3020	2.3001	−0.0019	121.40	121.33	−0.055
26	N555	2.3607	2.3586	−0.0021	122.93	122.86	−0.058
27	N575	2.3881	2.3859	−0.0022	123.64	123.57	−0.060
28	N509	2.5624	2.5594	−0.0029	128.08	127.99	−0.071
29	N549	2.6273	2.6242	−0.0031	129.69	129.59	−0.073
30	N569	2.6576	2.6544	−0.0033	130.44	130.34	−0.075

Statistic	Pressure difference (bar)	Discharge difference (%)
Maximum (absolute)	0.0033	0.075
Mean (absolute)	0.0011	0.033

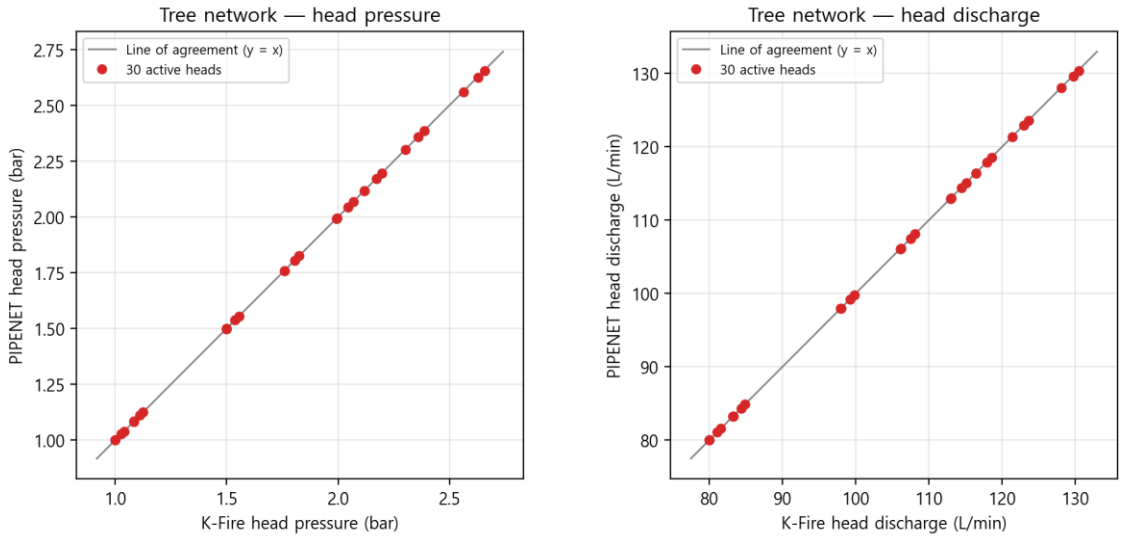


Figure 3. Tree network: comparison of head pressure and discharge. All 30 points lie on the line of agreement (y = x).

4.5 Conclusion

In the tree network, both programs identified the same most remote head (N523). The design flow difference is 0.03% and the maximum head pressure difference is 0.003 bar. All items meet the acceptance criteria.

The head pressure difference is close to zero at the most remote head and grows slightly for heads closer to the pump, because friction losses accumulate toward the pump. This is consistent in direction with the Hazen-Williams formula precision difference explained in Section 6.

5. Case 2: Grid Network

5.1 Network Overview

A gridded network in which 7 vertical lines are connected at both ends by top and bottom cross mains. The leftmost line is the main, and the supply point connects to the middle of this main. The 30 active heads are on the 4 branch lines on the right.

Item	Value
Number of pipes	247
Number of nodes	242
Head	112 (30 active, 82 inactive)
Number of independent loops	6
Total pipe length	546.50 m
Pipe sizes	25A, 40A, 50A, 65A, 100A
Supply point (pump) elevation	−0.5 m
Head elevation	0.5 m
Valves	1 Smolensky check valve

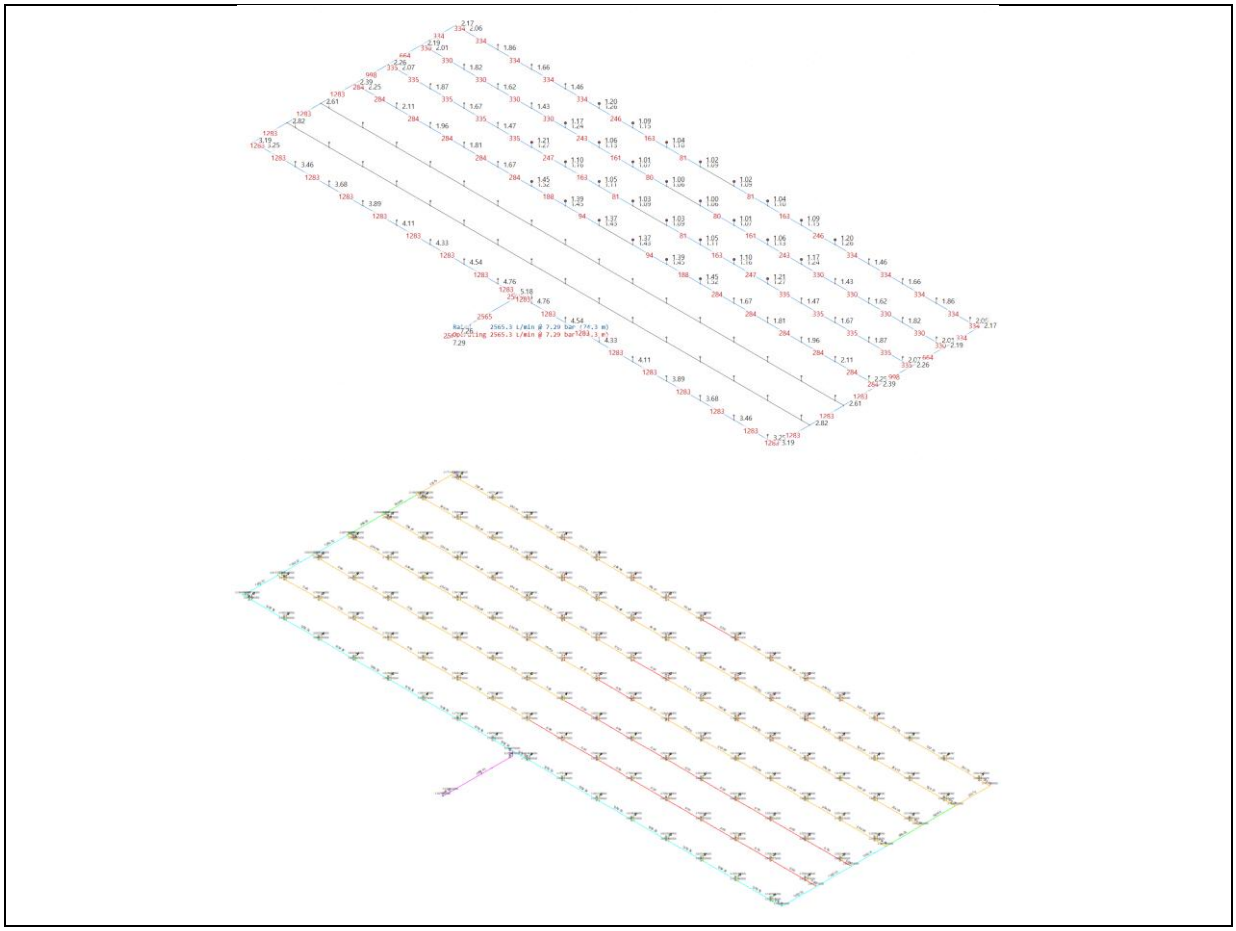


Figure 4. Grid network (top: K-Fire, bottom: PIPENET)

5.2 Input Consistency Check

Item	K-Fire	PIPENET	Remarks
Number of pipes	247	247	Same
Number of active heads	30	30	Same (K=80)
Number of inactive heads	82	82	Entered as switched off
25A total length (m)	3.00	3.00	Same
40A total length (m)	414.00	414.00	Same
50A total length (m)	3.50	3.50	Same
65A total length (m)	117.50	117.50	Same
100A total length (m)	8.50	8.50	Same
Total equivalent length (m)	193.898	193.896	Same (difference in printed digits)
Pipes with length/size/C mismatch		0	247 pipes checked one by one

5.3 Results Summary

Item	K-Fire	PIPENET	Difference	Result
Design flow (L/min)	**2,565.3**	**2,564.6**	−0.03%	Pass
Supply pressure (bar)	**7.286**	**7.257**	−0.029 bar (−0.39%)	Pass
Most remote head	**N486 (1.000 bar)**	**N486 (1.000 bar)**	Match	Pass
Max. head pressure difference			0.001 bar	Pass
Max. head discharge difference			0.05%	Pass
Max. pipe flow difference			0.05%	Pass
Max. node pressure difference			0.39%	Pass
Flow direction			All pipes match	Pass

5.4 Loop Flow Distribution

In a gridded network, water divides and flows along several paths. How much flows along each path is determined iteratively so that the pressure loss is the same on every path. The flow split is therefore the most important comparison item for a grid network.

Water entering at the supply point divides upward and downward in the left main. It then passes through the top and bottom cross mains and enters the 4 branch lines with active heads **from both**

ends simultaneously. Because the network is symmetrical top to bottom about the supply point, the top and bottom inflows are equal.

Section	Pipe	K-Fire (L/min)	PIPENET (L/min)	Difference (%)
Main: from supply point upward	P649	**1,282.6**	**1,282.0**	−0.050
Main: from supply point downward	P665	**1,282.6**	**1,282.0**	−0.050
Branch line 1: inflow at top end	P713	**284.2**	**284.1**	−0.032
Branch line 1: inflow at bottom end	P698	**284.2**	**284.1**	−0.032
Branch line 2: inflow at top end	P714	**334.8**	**334.8**	−0.014
Branch line 2: inflow at bottom end	P699	**334.8**	**334.8**	−0.014
Branch line 3: inflow at top end	P715	**329.8**	**329.7**	−0.028
Branch line 3: inflow at bottom end	P700	**329.8**	**329.7**	−0.028
Branch line 4: inflow at top end	P716	**333.8**	**333.7**	−0.032
Branch line 4: inflow at bottom end	P701	**333.8**	**333.7**	−0.032

The flows in the 4 branch lines are uneven, ranging from 284 to 335 L/min. Branch line 1, nearest the supply point, has fewer heads (6) and therefore less flow, while the other 3 lines have 8 heads each. Both programs calculated this distribution identically within 0.05%.

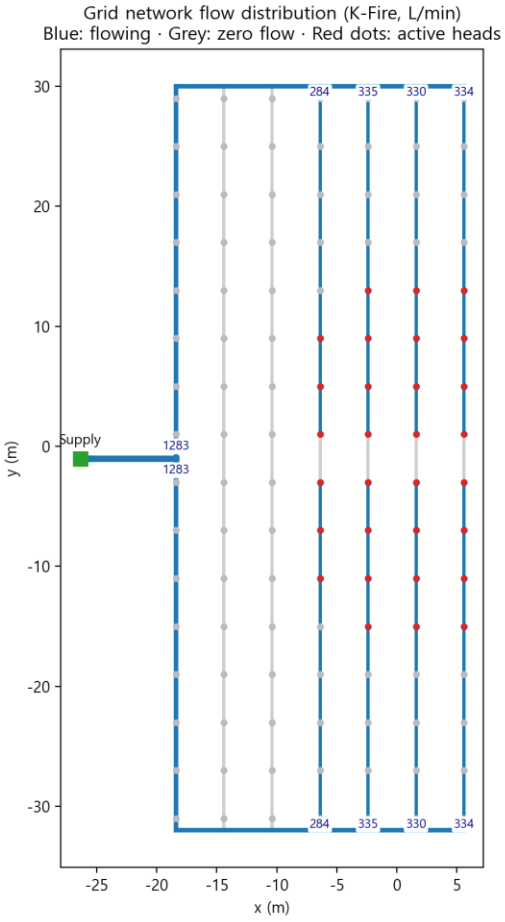


Figure 5. Grid network flow distribution (K-Fire). Grey pipes have zero flow: the 2 branch lines with only inactive heads, and the middle pipe of each branch line where the flows from the top and bottom meet. PIPENET also calculated zero flow in the same pipes.

5.5 Results by Head

No	Head	Pressure K-Fire (bar)	Pressure PIPENET (bar)	Difference (bar)	Discharge K-Fire (L/min)	Discharge PIPENET (L/min)	Difference (%)
1	N486	**1.0000**	**1.0000**	0.0000	**80.01**	**80.00**	−0.015
2	N509	**1.0000**	**1.0000**	0.0000	**80.01**	**80.00**	−0.015
3	N499	**1.0139**	**1.0139**	0.0000	**80.57**	**80.55**	−0.014
4	N507	**1.0139**	**1.0139**	0.0000	**80.57**	**80.55**	−0.014
5	N92	**1.0246**	**1.0246**	0.0000	**80.99**	**80.98**	−0.016
6	N103	**1.0246**	**1.0246**	0.0000	**80.99**	**80.98**	−0.016
7	N519	**1.0310**	**1.0310**	−0.0001	**81.24**	**81.23**	−0.017
8	N542	**1.0310**	**1.0310**	−0.0001	**81.24**	**81.23**	−0.017
9	N85	**1.0388**	**1.0388**	0.0000	**81.55**	**81.54**	−0.015
10	N104	**1.0388**	**1.0388**	0.0000	**81.55**	**81.54**	−0.015
11	N532	**1.0453**	**1.0453**	−0.0001	**81.80**	**81.79**	−0.017
12	N540	**1.0453**	**1.0453**	−0.0001	**81.80**	**81.79**	−0.017
13	N496	**1.0644**	**1.0644**	−0.0001	**82.55**	**82.53**	−0.016

No	Head	Pressure K-Fire (bar)	Pressure PIPENET (bar)	Difference (bar)	Discharge K-Fire (L/min)	Discharge PIPENET (L/min)	Difference (%)
14	N516	1.0644	1.0644	−0.0001	82.55	82.53	−0.016
15	N93	1.0905	1.0904	−0.0001	83.55	83.54	−0.018
16	N90	1.0905	1.0904	−0.0001	83.55	83.54	−0.018
17	N549	1.0973	1.0972	−0.0001	83.81	83.80	−0.019
18	N529	1.0973	1.0972	−0.0001	83.81	83.80	−0.019
19	N488	1.1733	1.1731	−0.0003	86.67	86.65	−0.025
20	N490	1.1733	1.1731	−0.0003	86.67	86.65	−0.025
21	N71	1.2019	1.2016	−0.0003	87.72	87.69	−0.026
22	N81	1.2019	1.2016	−0.0003	87.72	87.69	−0.026
23	N523	1.2093	1.2090	−0.0003	87.99	87.96	−0.027
24	N521	1.2093	1.2090	−0.0003	87.99	87.96	−0.027
25	N552	1.3672	1.3663	−0.0009	93.55	93.51	−0.046
26	N575	1.3672	1.3663	−0.0009	93.55	93.51	−0.046
27	N565	1.3857	1.3848	−0.0009	94.19	94.14	−0.046
28	N573	1.3857	1.3848	−0.0009	94.19	94.14	−0.046
29	N562	1.4532	1.4522	−0.0010	96.45	96.40	−0.049
30	N582	1.4532	1.4522	−0.0010	96.45	96.40	−0.049

Statistic	Pressure difference (bar)	Discharge difference (%)
Maximum (absolute)	0.0010	0.049
Mean (absolute)	0.0003	0.024

Heads have identical values in pairs because the network is symmetrical top to bottom. Both programs reproduced this symmetry.

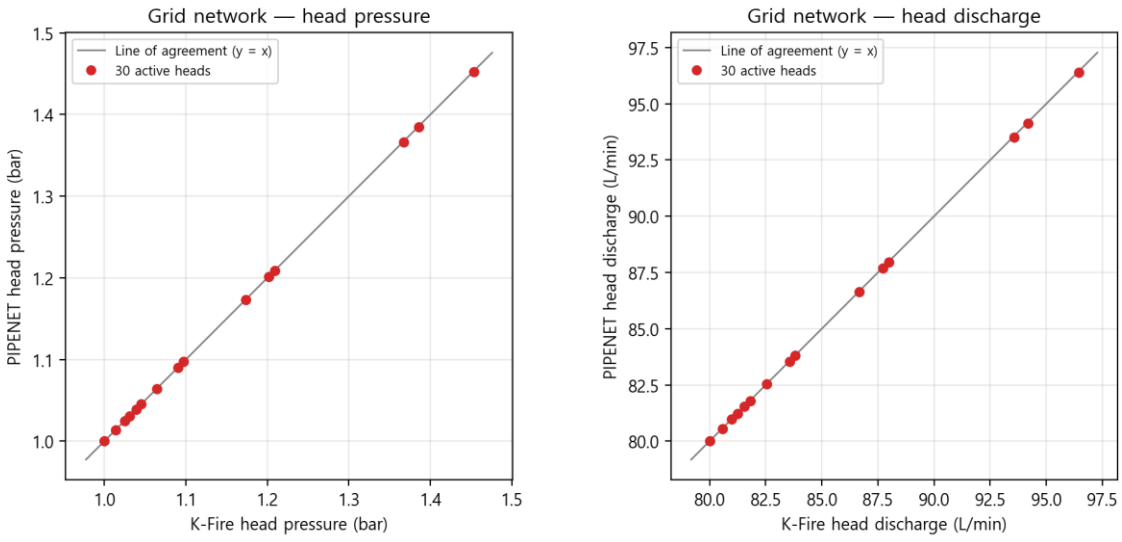


Figure 6. Grid network: comparison of head pressure and discharge.

5.6 Conclusion

In the grid network, both programs identified the same most remote head (N486). The maximum head pressure difference is 0.001 bar, and the loop flow distribution agrees within 0.05%. The two programs agreed even on which pipes have zero flow. All items meet the acceptance criteria.

The supply pressure difference (0.029 bar) is larger than in the tree network because a Smolensky check valve with a large equivalent length (100A, 70.7 m) is located at the supply point. This single section accounts for 0.012 bar. Because the entire supply flow (2,565 L/min) passes through this large-diameter section, the formula precision difference described in Section 6 is greatest here.

6. Analysis of Differences

6.1 Hazen-Williams Formulas of the Two Programs

The Hazen-Williams formula is an empirical formula originally developed in U.S. customary units. Each program converts it to metric units, and very small differences arise depending on how many digits of the coefficient and exponents are used.

Expressed in the same units (friction loss in bar/m, flow in L/min, internal diameter in mm), the two formulas are as follows.

$$p = \frac{k \cdot Q^a}{C^a \cdot d^b}$$

Category	Coefficient k	Flow exponent a	Diameter exponent b	How determined
K-Fire (EPANET precise formula)	6.073×10^5	1.852	4.871	Unit conversion of the EPANET formula
PIPENET	6.05×10^5	1.85	4.87	Back-calculated from the per-pipe friction losses in the PIPENET output

The PIPENET values are not estimates. When the flow and friction loss of each pipe in the PIPENET output are substituted into the formula above and solved back, all pipes with a friction loss of 0.01 bar or more agree within ±0.1%. The remaining ±0.1% is due to the number of digits printed in the output.

6.2 Differences by Pipe Size and Velocity

For the same pipe and the same flow, the friction loss differences between the two formulas are as follows (relative to K-Fire, C = 120).

Pipe sizes	Velocity 1 m/s	Velocity 3 m/s	Velocity 6 m/s
25A	−0.19%	+0.03%	+0.17%
40A	−0.06%	+0.16%	+0.30%
50A	+0.01%	+0.23%	+0.37%
65A	+0.09%	+0.31%	+0.45%
100A	+0.21%	+0.43%	+0.57%
150A	+0.33%	+0.55%	+0.69%

The differences range from −0.2 to +0.7%, and K-Fire calculates slightly higher losses at higher flows. This is because its flow exponent of 1.852 and diameter exponent of 4.871 are slightly larger than PIPENET's 1.85 and 4.87. K-Fire's 1.852 and 4.871 are more precise values carried to the third decimal place.

6.3 Effect on Results

A demand calculation finds the pump capacity required to provide 1.0 bar at the most remote head. The calculation therefore starts at 1.0 bar at the most remote head, and the required pressure increases toward the pump.

At the pump, the difference reaches 0.011 bar for the tree network and 0.029 bar for the grid network. Although insignificant, in both networks the large-diameter mains and valve sections carrying high flow have the greatest influence, so K-Fire calculated the supply pressure very slightly higher. This gives slightly more margin when selecting a pump, i.e., it is on the safe side.

In summary, the difference between the two programs is not a difference in calculation method but in how many digits of the same formula are used. Its magnitude is insignificant in practice, and the results of the two programs can be regarded as effectively identical.

7. Conclusions

1. In both the tree and grid networks, the demand calculation results of K-Fire and PIPENET met the acceptance criteria for all items. The maximum head pressure difference is 0.003 bar, and the maximum head discharge and pipe flow differences are 0.1%.
2. Both programs identified the same most remote head, and the loop flow distribution of the grid network and the flow direction in every pipe were also the same.
3. The differences come from the significant digits of the Hazen-Williams coefficient and exponents and from unit conversion precision. In effect, the calculation results of the two programs were identical.
4. K-Fire's application of tee equivalent lengths agreed with the NFPA 13 rules at all 184 branch points in the two networks.
5. K-Fire calculates elevations and fitting equivalent lengths directly from a drawing of the actual geometry. Input inconsistencies that can arise when the schematic and the calculation input are kept separate therefore cannot occur by design.

Based on these results, the hydraulic calculation results of K-Fire are judged to be as reliable as those of PIPENET, the most widely used program in Korea.

8. Appendix

8.1 Tree Network: Results for All Pipes

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P400	50A	0.50	3.200	596.8	596.6	-0.041	4.475	4.474
P435	100A	3.34	0.000	2565.3	2564.0	-0.049	4.909	4.908
P436	65A	0.50	5.898	862.1	861.7	-0.042	3.842	3.841
P471	100A	3.34	0.000	1703.2	1703.0	-0.012	3.260	3.259
P472	65A	0.50	5.898	857.0	856.7	-0.039	3.820	3.819
P507	65A	3.34	0.000	846.2	845.9	-0.031	3.772	3.770
P508	65A	0.50	5.898	846.2	845.9	-0.031	3.772	3.770
P509	65A	4.20	5.898	846.2	845.9	-0.031	3.772	3.770
P511	65A	4.20	0.000	846.2	845.9	-0.031	3.772	3.770
P513	65A	4.20	0.000	846.2	845.9	-0.031	3.772	3.770
P514	25A	0.50	1.764	128.1	128.0	-0.059	3.594	3.591
P515	50A	4.20	0.000	718.1	717.9	-0.026	5.384	5.383
P516	25A	0.50	1.764	121.4	121.3	-0.079	3.406	3.405
P517	50A	4.20	0.000	596.7	596.6	-0.016	4.474	4.473
P518	25A	0.50	1.764	116.4	116.4	-0.021	3.267	3.265
P519	50A	4.20	0.000	480.3	480.2	-0.015	3.601	3.600
P520	25A	0.50	1.764	113.0	112.9	-0.068	3.170	3.169
P521	40A	4.20	0.000	367.3	367.3	+0.002	4.398	4.397
P522	25A	0.50	1.764	106.1	106.1	-0.012	2.978	2.977
P523	32A	4.20	0.000	261.2	261.2	+0.008	4.229	4.229
P524	25A	0.50	1.764	97.9	97.9	-0.009	2.748	2.748
P525	25A	4.20	0.000	163.2	163.3	+0.036	4.581	4.581
P526	25A	0.50	1.764	83.2	83.2	+0.004	2.336	2.336
P527	25A	4.20	0.000	80.0	80.0	+0.007	2.245	2.245
P528	25A	0.50	0.706	80.0	80.0	+0.007	2.245	2.245
P543	65A	4.20	5.898	857.0	856.7	-0.039	3.820	3.819
P545	65A	4.20	0.000	857.0	856.7	-0.039	3.820	3.819
P547	65A	4.20	0.000	857.0	856.7	-0.039	3.820	3.819
P548	25A	0.50	1.764	129.7	129.6	-0.070	3.639	3.636
P549	50A	4.20	0.000	727.3	727.1	-0.034	5.454	5.452
P550	25A	0.50	1.764	122.9	122.9	-0.027	3.450	3.448
P551	50A	4.20	0.000	604.4	604.3	-0.019	4.532	4.531
P552	25A	0.50	1.764	117.9	117.9	-0.005	3.308	3.307
P553	50A	4.20	0.000	486.5	486.4	-0.022	3.648	3.647
P554	25A	0.50	1.764	114.4	114.4	-0.017	3.211	3.209
P555	40A	4.20	0.000	372.1	372.1	+0.003	4.455	4.455

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P556	25A	0.50	1.764	107.5	107.4	-0.071	3.016	3.015
P557	32A	4.20	0.000	264.6	264.6	-0.005	4.285	4.285
P558	25A	0.50	1.764	99.2	99.2	-0.019	2.784	2.783
P559	25A	4.20	0.000	165.4	165.4	-0.002	4.641	4.642
P560	25A	0.50	1.764	84.3	84.3	+0.004	2.367	2.367
P561	25A	4.20	0.000	81.1	81.1	+0.004	2.274	2.275
P562	25A	0.50	0.706	81.1	81.1	+0.004	2.274	2.275
P563	65A	4.20	5.898	862.1	861.7	-0.042	3.842	3.841
P565	65A	4.20	0.000	862.1	861.7	-0.042	3.842	3.841
P567	65A	4.20	0.000	862.1	861.7	-0.042	3.842	3.841
P568	25A	0.50	1.764	130.4	130.3	-0.104	3.660	3.657
P569	50A	4.20	0.000	731.6	731.4	-0.031	5.486	5.484
P570	25A	0.50	1.764	123.6	123.6	-0.036	3.470	3.467
P571	50A	4.20	0.000	608.0	607.8	-0.030	4.559	4.557
P572	25A	0.50	1.764	118.6	118.5	-0.076	3.328	3.326
P573	50A	4.20	0.000	489.4	489.3	-0.018	3.669	3.669
P574	25A	0.50	1.764	115.1	115.0	-0.074	3.229	3.228
P575	40A	4.20	0.000	374.3	374.3	-0.001	4.481	4.481
P576	25A	0.50	1.764	108.1	108.1	-0.006	3.033	3.033
P577	32A	4.20	0.000	266.2	266.2	+0.001	4.311	4.311
P578	25A	0.50	1.764	99.8	99.8	-0.015	2.800	2.800
P579	25A	4.20	0.000	166.4	166.4	-0.002	4.669	4.669
P580	25A	0.50	1.764	84.9	84.9	+0.006	2.381	2.381
P581	25A	4.20	0.000	81.5	81.5	+0.003	2.288	2.288
P582	25A	0.50	0.706	81.5	81.5	+0.003	2.288	2.288
P583	50A	4.20	3.200	596.8	596.6	-0.041	4.475	4.474
P585	50A	4.20	0.000	596.8	596.6	-0.041	4.475	4.474
P587	50A	4.20	0.000	596.8	596.6	-0.041	4.475	4.474
P589	50A	4.20	0.000	596.8	596.6	-0.041	4.475	4.474
P591	50A	4.20	0.000	596.8	596.6	-0.041	4.475	4.474
P592	25A	0.50	1.764	116.5	116.4	-0.046	3.268	3.266
P593	50A	4.20	0.000	480.4	480.3	-0.019	3.602	3.601
P594	25A	0.50	1.764	113.0	112.9	-0.093	3.171	3.169
P595	40A	4.20	0.000	367.4	367.3	-0.024	4.399	4.398
P596	25A	0.50	1.764	106.1	106.1	-0.037	2.978	2.977
P597	32A	4.20	0.000	261.2	261.2	-0.018	4.231	4.230
P598	25A	0.50	1.764	98.0	97.9	-0.025	2.749	2.748
P599	25A	4.20	0.000	163.3	163.3	+0.010	4.582	4.582
P600	25A	0.50	1.764	83.3	83.3	-0.010	2.337	2.336
P601	25A	4.20	0.000	80.0	80.0	-0.007	2.245	2.245

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P602	25A	0.50	0.706	80.0	80.0	-0.007	2.245	2.245
P651	150A	3.00	4.494	3162.1	3161.0	-0.035	2.775	2.774
P653	150A	2.00	4.494	3162.1	3161.0	-0.035	2.775	2.774
P654	150A	1.00	4.494	3162.1	3161.0	-0.035	2.775	2.774
P655	150A	1.00	4.494	3162.1	3161.0	-0.035	2.775	2.774
P657	125A	5.00	8.164	3162.1	3161.0	-0.035	3.964	3.963
P658	150A	1.00	17.347	3162.1	3161.0	-0.035	2.775	2.774
P660	150A	22.00	4.494	3162.1	3161.0	-0.035	2.775	2.774
P663	150A	5.00	4.494	3162.1	3161.0	-0.035	2.775	2.774
P664	150A	8.00	10.450	3162.1	3161.0	-0.035	2.775	2.774
P665	150A	1.00	0.000	3162.1	3161.0	-0.035	2.775	2.774

Pipes with zero flow (0 pipes; e.g., branches to inactive heads) are omitted from the table. Both programs calculated zero flow for them.

8.2 Grid Network: Results for All Pipes

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P71	40A	0.50	2.763	81.0	81.0	-0.012	0.970	0.970
P72	40A	4.00	0.000	81.0	81.0	-0.012	0.970	0.970
P73	40A	0.50	2.763	81.5	81.5	-0.012	0.976	0.976
P74	40A	4.00	0.000	162.5	162.5	-0.024	1.946	1.946
P75	40A	0.50	2.763	83.6	83.5	-0.015	1.000	1.000
P76	40A	4.00	0.000	246.1	246.1	+0.003	2.946	2.946
P77	40A	0.50	2.763	87.7	87.7	-0.029	1.050	1.050
P78	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P80	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P82	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P84	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P87	40A	0.50	2.763	81.0	81.0	-0.012	0.970	0.970
P89	40A	4.00	0.000	81.0	81.0	-0.012	0.970	0.970
P90	40A	0.50	2.763	81.5	81.5	-0.012	0.976	0.976
P91	40A	4.00	0.000	162.5	162.5	-0.025	1.946	1.946
P92	40A	0.50	2.763	83.6	83.5	-0.015	1.000	1.000
P93	40A	4.00	0.000	246.1	246.1	+0.003	2.946	2.946
P94	40A	0.50	2.763	87.7	87.7	-0.029	1.050	1.050
P95	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P97	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P99	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P101	40A	4.00	0.000	333.8	333.7	-0.032	3.997	3.996
P485	40A	0.50	2.763	80.0	80.0	-0.015	0.958	0.958
P486	40A	4.00	0.000	80.0	80.0	-0.015	0.958	0.958
P487	40A	0.50	2.763	80.6	80.5	-0.020	0.965	0.965
P488	40A	4.00	0.000	160.6	160.6	+0.014	1.923	1.922
P489	40A	0.50	2.763	82.5	82.5	-0.022	0.988	0.988
P490	40A	4.00	0.000	243.1	243.1	-0.011	2.911	2.910
P491	40A	0.50	2.763	86.7	86.7	-0.020	1.038	1.037
P492	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P494	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P496	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P498	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P501	40A	0.50	2.763	80.0	80.0	-0.015	0.958	0.958
P503	40A	4.00	0.000	80.0	80.0	-0.015	0.958	0.958
P504	40A	0.50	2.763	80.6	80.5	-0.020	0.965	0.965
P505	40A	4.00	0.000	160.6	160.6	+0.014	1.923	1.922
P506	40A	0.50	2.763	82.5	82.5	-0.022	0.988	0.988
P507	40A	4.00	0.000	243.1	243.1	-0.010	2.911	2.910
P508	40A	0.50	2.763	86.7	86.7	-0.020	1.038	1.037
P509	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P511	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P513	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P515	40A	4.00	0.000	329.8	329.7	-0.028	3.949	3.948
P518	40A	0.50	2.763	81.2	81.2	-0.016	0.973	0.973
P519	40A	4.00	0.000	81.2	81.2	-0.016	0.973	0.973
P520	40A	0.50	2.763	81.8	81.8	-0.018	0.979	0.979
P521	40A	4.00	0.000	163.0	163.0	-0.029	1.952	1.952
P522	40A	0.50	2.763	83.8	83.8	-0.015	1.003	1.003
P523	40A	4.00	0.000	246.9	246.8	-0.024	2.956	2.955
P524	40A	0.50	2.763	88.0	88.0	-0.030	1.053	1.053
P525	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P527	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P529	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P531	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P534	40A	0.50	2.763	81.2	81.2	-0.016	0.973	0.973
P536	40A	4.00	0.000	81.2	81.2	-0.016	0.973	0.973
P537	40A	0.50	2.763	81.8	81.8	-0.018	0.979	0.979
P538	40A	4.00	0.000	163.0	163.0	-0.029	1.952	1.952

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P539	40A	0.50	2.763	83.8	83.8	-0.015	1.003	1.003
P540	40A	4.00	0.000	246.9	246.8	-0.024	2.956	2.955
P541	40A	0.50	2.763	88.0	88.0	-0.030	1.053	1.053
P542	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P544	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P546	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P548	40A	4.00	0.000	334.8	334.8	-0.014	4.009	4.008
P551	40A	0.50	2.763	93.6	93.5	-0.046	1.120	1.120
P552	40A	4.00	0.000	93.6	93.5	-0.046	1.120	1.120
P553	40A	0.50	2.763	94.2	94.1	-0.049	1.128	1.127
P554	40A	4.00	0.000	187.7	187.7	-0.021	2.248	2.247
P555	40A	0.50	2.763	96.5	96.4	-0.054	1.155	1.154
P556	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P558	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P560	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P562	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P564	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P567	40A	0.50	2.763	93.6	93.5	-0.046	1.120	1.120
P569	40A	4.00	0.000	93.6	93.5	-0.046	1.120	1.120
P570	40A	0.50	2.763	94.2	94.1	-0.049	1.128	1.127
P571	40A	4.00	0.000	187.7	187.7	-0.021	2.248	2.247
P572	40A	0.50	2.763	96.5	96.4	-0.054	1.155	1.154
P573	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P575	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P577	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P579	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P581	40A	4.00	0.000	284.2	284.1	-0.032	3.403	3.401
P649	65A	2.00	5.898	1282.6	1282.0	-0.050	5.717	5.716
P651	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P653	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P655	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P657	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P659	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P661	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P663	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P665	65A	2.00	5.898	1282.6	1282.0	-0.050	5.717	5.716
P667	100A	0.50	3.453	2565.3	2565.0	-0.011	4.910	4.908
P668	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P670	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P672	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716

Pipe	Pipe sizes	Length (m)	Equivalent length (m)	Flow K-Fire (L/min)	Flow PIPENET (L/min)	Difference (%)	Velocity K-Fire (m/s)	Velocity PIPENET (m/s)
P674	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P676	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P678	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P680	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P695	65A	1.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P698	40A	1.00	2.763	284.2	284.1	-0.032	3.403	3.401
P699	40A	1.00	2.763	334.8	334.8	-0.014	4.009	4.008
P700	40A	1.00	2.763	329.8	329.7	-0.028	3.949	3.948
P701	40A	1.00	1.381	333.8	333.7	-0.032	3.997	3.996
P703	65A	4.00	2.869	1282.6	1282.0	-0.050	5.717	5.716
P704	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P705	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P706	65A	4.00	0.000	998.4	998.3	-0.015	4.450	4.449
P707	65A	4.00	0.000	663.6	663.5	-0.015	2.958	2.957
P708	65A	4.00	0.000	333.8	333.7	-0.032	1.488	1.488
P710	65A	1.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P713	40A	1.00	2.763	284.2	284.1	-0.032	3.403	3.401
P714	40A	1.00	2.763	334.8	334.8	-0.014	4.009	4.008
P715	40A	1.00	2.763	329.8	329.7	-0.028	3.949	3.948
P716	40A	1.00	1.381	333.8	333.7	-0.032	3.997	3.996
P718	65A	4.00	2.869	1282.6	1282.0	-0.050	5.717	5.716
P719	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P720	65A	4.00	0.000	1282.6	1282.0	-0.050	5.717	5.716
P721	65A	4.00	0.000	998.4	998.3	-0.015	4.450	4.449
P722	65A	4.00	0.000	663.6	663.5	-0.015	2.958	2.957
P723	65A	4.00	0.000	333.8	333.7	-0.032	1.488	1.488
P730	100A	7.10	70.681	2565.3	2565.0	-0.011	4.910	4.908
P731	100A	0.90	0.000	2565.3	2565.0	-0.011	4.910	4.908

Pipes with zero flow (120 pipes; e.g., branches to inactive heads) are omitted from the table. Both programs calculated zero flow for them.

8.3 Excerpt of the Original PIPENET Output

The nozzle (head) results table and the supply point results table are reproduced as is from the PIPENET results output. Node numbers are the same as in the K-Fire drawings ("/0" in PIPENET labels is a PIPENET-specific suffix appended to the number).

Tree network

FLOW THROUGH NOZZLES

Nozzle Label	Input Label	Inlet Press (bar G)	Req. Flow (lit/min)	Flowrate (lit/min)	% Deviation	Req. FlowDens (lit/min /metres **2)	FlowDens
N509/0	N509/0	0.25594E+01	80.0000	127.9860	59.98		
N530/0	N530/0	0.23001E+01	80.0000	121.3283	51.66		
N528/0	N528/0	0.21160E+01	80.0000	116.3723	45.47		
N514/0	N514/0	0.19928E+01	80.0000	112.9345	41.17		
N526/0	N526/0	0.17585E+01	80.0000	106.0863	32.61		
N521/0	N521/0	0.14984E+01	80.0000	97.9276	22.41		
N517/0	N517/0	0.10830E+01	80.0000	83.2530	4.07		
N523/0	N523/0	0.10000E+01	80.0000	80.0000 *	0.00		
N549/0	N549/0	0.26242E+01	80.0000	129.5950	61.99		
N555/0	N555/0	0.23586E+01	80.0000	122.8622	53.58		
N551/0	N551/0	0.21701E+01	80.0000	117.8501	47.31		
N552/0	N552/0	0.20439E+01	80.0000	114.3733	42.97		
N545/0	N545/0	0.18039E+01	80.0000	107.4469	34.31		
N560/0	N560/0	0.15374E+01	80.0000	99.1946	23.99		
N554/0	N554/0	0.11117E+01	80.0000	84.3510	5.44		
N559/0	N559/0	0.10267E+01	80.0000	81.0610	1.33		
N569/0	N569/0	0.26544E+01	80.0000	130.3375	62.92		
N575/0	N575/0	0.23859E+01	80.0000	123.5701	54.46		
N571/0	N571/0	0.21953E+01	80.0000	118.5322	48.17		
N572/0	N572/0	0.20677E+01	80.0000	115.0374	43.80		
N565/0	N565/0	0.18250E+01	80.0000	108.0750	35.09		
N580/0	N580/0	0.15556E+01	80.0000	99.7794	24.72		
N574/0	N574/0	0.11251E+01	80.0000	84.8580	6.07		
N579/0	N579/0	0.10391E+01	80.0000	81.5508	1.94		
N591/0	N591/0	0.21165E+01	80.0000	116.3866	45.48		
N592/0	N592/0	0.19933E+01	80.0000	112.9484	41.19		
N585/0	N585/0	0.17589E+01	80.0000	106.0994	32.62		
N600/0	N600/0	0.14988E+01	80.0000	97.9398	22.42		
N594/0	N594/0	0.10833E+01	80.0000	83.2635	4.08		
N599/0	N599/0	0.10003E+01	80.0000	80.0101	0.01		

FLOW AT INLETS

Inlet Node	Pressure (bar G)	Flowrate (lit/min)	Equivalent K-factor (lit/min , bar G)
N660/0	5.223	3161.	1383.1

Grid network

FLOW THROUGH NOZZLES

Nozzle Label	Input Label	Inlet Press (bar G)	Req. Flow (lit/min)	Flowrate (lit/min)	% Deviation	Req. FlowDens (lit/min /metres **2)	FlowDens
N92/0	N92/0	0.10246E+01	80.0000	80.9773	1.22		
N85/0	N85/0	0.10388E+01	80.0000	81.5374	1.92		
N93/0	N93/0	0.10904E+01	80.0000	83.5380	4.42		
N71/0	N71/0	0.12016E+01	80.0000	87.6927	9.62		
N103/0	N103/0	0.10246E+01	80.0000	80.9773	1.22		
N104/0	N104/0	0.10388E+01	80.0000	81.5374	1.92		
N90/0	N90/0	0.10904E+01	80.0000	83.5380	4.42		
N81/0	N81/0	0.12016E+01	80.0000	87.6926	9.62		
N486/0	N486/0	0.10000E+01	80.0000	80.0000 *	0.00		
N507/0	N507/0	0.10139E+01	80.0000	80.5543	0.69		
N516/0	N516/0	0.10644E+01	80.0000	82.5343	3.17		
N490/0	N490/0	0.11731E+01	80.0000	86.6460	8.31		
N509/0	N509/0	0.10000E+01	80.0000	80.0000	0.00		
N499/0	N499/0	0.10139E+01	80.0000	80.5543	0.69		
N496/0	N496/0	0.10644E+01	80.0000	82.5343	3.17		
N488/0	N488/0	0.11731E+01	80.0000	86.6460	8.31		
N519/0	N519/0	0.10310E+01	80.0000	81.2292	1.54		
N540/0	N540/0	0.10453E+01	80.0000	81.7908	2.24		
N549/0	N549/0	0.10972E+01	80.0000	83.7967	4.75		
N523/0	N523/0	0.12090E+01	80.0000	87.9625	9.95		
N542/0	N542/0	0.10310E+01	80.0000	81.2292	1.54		
N532/0	N532/0	0.10453E+01	80.0000	81.7908	2.24		
N529/0	N529/0	0.10972E+01	80.0000	83.7967	4.75		
N521/0	N521/0	0.12090E+01	80.0000	87.9625	9.95		
N552/0	N552/0	0.13663E+01	80.0000	93.5098	16.89		
N573/0	N573/0	0.13848E+01	80.0000	94.1429	17.68		
N582/0	N582/0	0.14522E+01	80.0000	96.4049	20.51		
N575/0	N575/0	0.13663E+01	80.0000	93.5098	16.89		
N565/0	N565/0	0.13848E+01	80.0000	94.1429	17.68		
N562/0	N562/0	0.14522E+01	80.0000	96.4049	20.51		

(82 inactive head rows omitted - zero flow)

FLOW AT INLETS

Inlet Node	Pressure (bar G)	Flowrate (lit/min)	Equivalent K-factor (lit/min , bar G)

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N240/0          7.257          2565.           952.01
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