PROJECT REPORT

To:
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Energy Savings Related to Circuit Solver

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Abstract

The goal of this project was to determine the reduction in heat loss rate in the hot water circulation system in a hypothetical hotel when the traditionally used manually adjusted pressure differential flow control valves (FCV valves) are replaced with the 'circuit solver' valves. The FCV valves are manually adjusted to achieve a 1 GPM flow rate. The circuit solver valves, however, adjusted the flow rate until their upstream flow temperature achieves a given setting.

All the data generated in this study was obtained with numerical simulation. The work did not include a design optimization of the system in which the diameters of the branches would have been varied to achieve minimum heat loss rate. Also, there was no pump optimization.

The final conclusion of the study was that for the particular hypothetical hotel case the **SOLVER circuit provides an about 6.5% reduction in aggregate heat loss rate** during the low usage hours.

Scope of work

The hot water recirculation case with the FCV valves will be referred to as the FCV case and the hot water recirculation case with the circuit solver valves will be referred to as the SOLVER case. Figure 1 defines both cases as the fluid network connectivity is the same, only the diameters of the return lines are different for the SOLVER problem.

The work did not include a design optimization of the system in which the diameters of the branches are varied to achieve minimum heat loss rate. Only the configurations shown in Fig.1 was analyzed. Also, there was no pump optimization. Pump flow was a result of the SOLVER case study with which the temperature set point was achieved, and it was 28 GPM for the FCV case since there are 28 flow control valves with 1 GPM each.

Simulation Tool

The work was carried out in the modeling environment 'Matlab'. Matlab m-file programs were written and used to generate the results and create plots. Listings of these programs can be found in Appendix A.

Details of the Modeled System

The schematic of the hot water recirculation system is shown in Figure 1. There are 28 floors in a hypothetical hotel, each identical in terms of the geometry of the lines and the valves. The length and diameters of the hot water copper pipes and the type and thickness of the applied insulation are also shown in the figure. Furthermore, the 00_1, 00_2, etc. identifiers of the individual pipe pieces or 'branches' are also shown. These identifiers can be used to match the results in Tables 3 & 4 to the branches in Figure 1.

Ambient temperature over all copper pipes was assumed to be 75degF. Temperature of the flow from the thermostatic mixing valve was 120degF. The circuit solver valves are set to keep 115 deg F upstream.

Nominal Diam.	Nominal Diam.	OD	Wall thickness	ID
½"	0.500"	0.625"	0.040"	0.545"
¾"	0.750"	0.875"	0.045"	0.785"
1"	1.000"	1.125"	0.050"	1.025"
1 ¼"	1.250"	1.375"	0.055"	1.265"
1 ½"	1.500"	1.625"	0.060"	1.505"
2"	2.000"	2.125"	0.070"	1.985"
2 ½"	2.500"	2.625"	0.080"	2.465"

Type L copper pipe nominal dimensions

Type L copper pipes, with the above nominal ID and OD dimensions were used. Thermal conductivity of the copper material was 400 W/(mK). The insulation was assumed coated fiber glass pipe covering, with an R value of 3.8 (equivalent to 0.038 W/(mK) thermal conductivity, taken from Table A.3 of Ref. 1.). In compliance with the ASHRAE guidelines (Ref 1), in this study, all pipes less than 1 ½" nominal diameter used 1" thick insulation and all pipes 1 ½" and above nominal diameters used 1 ½" thick insulation.

Assumptions and Simplifications Incorporated into the Simulation Model

All results were generated for steady state conditions, both for the FCV case and for the SOLVER case. Hot water usage was not accounted for. Results represent overnight conditions when no usage occurs. Flow area vs. pressure differential and vs. upstream temperature was not known for either of the valves. Flow rate was set to 1 GPM for the FCV case on all valves and it was simulation result for the SOLVER case, based on achieving the upstream temperature target. Pressure levels have very little effect on the water material properties, and flow rates were determined by the flow setting for the FCV case and temperature setting for the SOLVER case. Pressure is neither input, nor a relevant output. (However, it should be noted, that - with very little work - the program can be extended to calculate the proper pressures in the system). Specific heat of water was considered constant, which is a very good assumption for the relevant pressure and temperature range. Density, thermal conductivity, and viscosity of water were function of the temperature only, which again is a good approximation in the relevant temperature/pressure ranges.

The heat loss rate was calculated based on the thermal resistance between the moving water and the copper pipe inner wall, the thermal resistance across the wall of the copper pipe, and the thermal resistance across the insulation. Thermal resistance across the insulation / ambient air interface was considered zero, that is, the outer surface of the insulation was assumed being at ambient temperature. Axial heat transfer in the pipe

wall was not considered. Each branch was calculated by segments, each segment in each branch being 1 foot in length. Therefore, for the 12 foot risers/returns, distributed parameter model with 12 segments was used, that is, heat transfer was calculated in the 12 segments separately and added up for the whole branch. Also, temperature drop of the water along the pipes was accounted for.

Heat transfer rate from the water to the copper pipe was calculated with the Dittus-Boelter equation (Eq. 8.58, Ref. 2). The thermal resistance of the copper pipe was calculated with Eq. 3.26 of Ref. 2.

Inside the programs mainly metric unit system is used. When different, the appropriate units are noted.

Summary Descriptions of the Simulation Models

The basic building block of the simulation model is the matlab function 'branch.m' (see Appendix A for listing) that takes as input the pipe geometry, the inlet temperature and mass flow rate, and calculates the heat loss rate and the branch exit flow properties. For the FCV system, the 'branch.m' function is called from the main program 'fcvsystem.m'. The 'fcvsystem.m' program then calls the 'branch.m' function once for each branch in an order such that the downstream temperature from one branch can be used as upstream temperature to the next branch or branches downstream. For the FCV problem, the flow rates are known in each branch at the outset, as the connectivity of the branches is such that the flows through the recirculation valves determine the flow in all branches. Therefore, only one call per branch is needed to the 'branch.m' function and all results are generated. The 'postprocess.m' program can then be used for creating plots and writing tabulated results for all branches into the 'results.txt' file.

The method is a bit more complicated for the SOLVER system. The same 'branch.m' function can be used for the basic branch simulation model. Once the flow rates are known, the 'solversystem.m' can be used to generate all results, and again the 'postprocess.m' program can be used for creating plots and writing tabulated results. The 'solversystem.m' program is essentially the same as the 'fcvsystem.m' program, except the vector of valve flow rates are read from a file and the return line geometry is defined differently according to Fig. 1.

However, there are intermediate steps needed to determine the correct flow rates through the valves of the SOLVER system that result in the target valve upstream temperatures for each valve. An iteration program 'solveriteration.m' is used, which makes multiple calls to the 'solversystem01.m' function. The 'solversystem01.m' function contains essentially the same code as the 'solversystem.m' program does, but it is a function, with the flow rate vector being the input and the valve upstream temperatures being the output.

The 'solveriteration.m' program calls the 'solversystem01.m' function each time with an updated vector of valve flows until the temperature targets are achieved. This iterative

algorithm can be described as follows: The SOLVER valve upstream temperatures are evaluated with an initial guess for the vector of valve flow rates, by one call to the 'solversystem01.m' function. Then, the error between the target and the actual temperatures are calculated. The valve for which the temperature error was the greatest is identified next. An inner iteration loop is then executed on the flow rate of this valve until the temperature error for that valve becomes sufficiently close to zero (practically, an error limit of 0.01 deg F was chosen). By changing the flow on this valve, valve upstream temperatures for all the other valves in the system also change, but by a lot smaller amount than in the valve for which the flow rate is modified. Once this convergence was achieved, the new error vector is examined for the largest error. Of course, the largest error would be found for a different valve. Now the flow of this valve with the biggest temperature error is iterated upon until the temperature error disappears. This process is repeated in the outer iteration loop until all SOLVER valve upstream temperatures are within a target +/- 0.02 deg F error limit. Note: for the specific problem investigated, it took 53 iterations to arrive at the final valve flow rate vector. When the iteration has converged, as a final step, the 'solveriteration.m' program writes the valve flow rate vector into file 'qmfile99.mat', which file will be read by the 'solversystem.m' program to generate all the final results.

It was required that a minimum flow rate of 0.1 GPM be maintained on all SOLVER valves even if the valve inlet temperature was higher than the target. This was done in order to keep water moving in the circuit at all times and therefore comply with water quality standards and to prevent overheating of the recirculation pump. As it turned out, this limit did not come into play, as even the lowest valve flow rate was 0.1271 GPM. Since the limit didn't come into play, the algorithm did not have a provision of limiting the flow to at least 0.1 GPM, but if further work is conducted, this can be easily implemented.

In summary, for the FCV problem, execute the ' fcvsystem.m' program, then execute the 'postprocess.m' program to get output plots and tabulated output in the 'results.txt' file. For the SOLVER problem, execute the 'solveriteration.m' program first. Then execute the 'solversystem.m' program (which will read the 'qmfile99.mat' file written by 'solveriteration.m' to get the vector of valve flow rates). Finally, run the 'postprocess.m' program to get the output plots and the tabulated output in the 'results.txt' file. The 'results.txt' file contains upstream and downstream temperatures in deg F, exit velocity in ft/sec, and heat loss rate in BTU/hr units, for each branch.

All the program listings are included in Appendix A of this document.

Results

The most important final results is a comparison of the aggregate heat loss rate in the FCV system vs. in the SOLVER system, which is the sum of heat loss rates in all of the branches in each system, respectively:

FCV system aggregate heat loss rate: 14738.94 BTU/hr
SOLVER system aggregate heat loss rate: 13794.72 BTU/hr

The aggregate heat loss rates in the two systems for only the subsystems upstream of the recirculation valves were also added up:

FCV system, aggregate heat loss rate upstream of valves: 11827.70
SOLVER system, aggregate heat loss rate upstream of valves: 11130.86

Pump flow rates (assumed to be the total flow rate entering the system through branch _00_1 and returning from the system through branch _00_2) for the two systems are:

FCV system total flow rate: 28.00 GPM (simply 28 times 1 GPM per floor)
SOLVER system total flow rate: 4.453 GPM (sum of the vector elements in Table 1)

The FCV valve upstream temperatures are shown in Table 1. The valve flow rate vector for the SOLVER case is shown in Table 2

The heat loss rates in the individual branches of the FCV and SOLVER systems are provided in Tables 3, and 4, respectively. In these tables, the inlet and exit temperatures and flow velocities for each branch are also included.

The plot of temperatures along the risers and the return lines vs. floor are plotted in Fig. 2 for the FCV problem and in Fig.4 for the SOLVER problem. The temperature in the nodes on the individual floors are shown in Fig. 3 for the FCV problem and in Fig 5 for the SOLVER problem.

Discussion of the Results

Initially, one would think that the flow rates inside the copper pipes have a significant influence on the overall heat loss rate, and therefore, the circuit solver valves would have a dramatic improvement on aggregate system heat loss rate. However, this did not turn out to be case. The main reason is that the thermal resistance of the insulation is completely overwhelming compared to the thermal resistance of the water/ copper pipe interface, the copper pipe itself, and the insulation/ air interface. The low thermal resistance in the water-to-copper interface means that even if this resistance goes up by a large factor (as it would with lower flow rate), the temperature drop from the water to the copper pipe will still be a small fraction of the total temperature drop from the water to the ambient air. In turn, the temperature drop across the insulation remains almost the same regardless of flow velocity. Since the temperature drop across the insulation determines the heat loss rate, the heat loss rate will hardly change at all due to a change in water flow rate.

On the macro-scale, however, the flow rates make a difference because, for the same heat loss rate, slower flow means higher water temperature drop as the water flows downstream. With higher temperature drop, the temperature in a branch further downstream will be lower and the heat transfer rate will be lower as well. Practically all of the benefits of the circuit solver system seem to derive from this fact.

It is true that the flow rate is much lower in the SOLVER system, but the returning heat energy is relatively similar to that for the FCV system, because the returning temperature is also much lower.

As a final conclusion, it can be said that for the particular hypothetical hotel case the SOLVER circuit provides an about 6.5% reduction in aggregate heat loss rate. However, the hot water temperature on the individual floors will also be somewhat lower than for the FCV system case.

Recommendation of Further Study

Further studies could include ones in which some of the simplifications applied here are removed. The one simplification whose removal may result in the most significant change compared to the results presented herein may be the assumption of the outer surface of the insulation maintaining essentially the same temperature as the ambient air. This study would require some assumption on the air velocity over the insulated hot water lines, which is difficult to estimate and probably quite variable from branch to branch. The aggregate heat loss rates for both the FCV and the SOLVER problem will be lower due to this added thermal resistance. However, it is still expected that the heat energy saved by the SOLVER system expressed as a percentage of the FCV system heat loss would be nearly the same 6.5% shown above, because both system would be affected about the same.

Other further studies may include checking the FCV and SOLVER systems against each other for hypothetical usage cases. It is expected that with water take-out by users on various floors, the FCV system will reach even higher temperatures on average, and the aggregate heat loss rate will increase. For cases with usage the valve flow areas will be kept the same as they were for the overnight no-usage case, subject of this report. The rationale is that – since these valves are manually adjusted – their setting will not change for significant amounts of time. On the other hand, usage will not result in significantly higher flow rates in the SOLVER system because the valves will cut down on their flow areas in order to maintain the set temperature. The overall system temperature will not change much relative to the overnight no-usage condition, and therefore, the aggregate heat loss rate of the system will not change much either.

In summary, when usage is accounted for, the difference between the FCV system's average temperature and the SOLVER system's average temperature may be even higher than for the no-usage case, and therefore, the difference between the aggregate heat loss rates of the two systems may be even higher than during the no-usage hours examined in

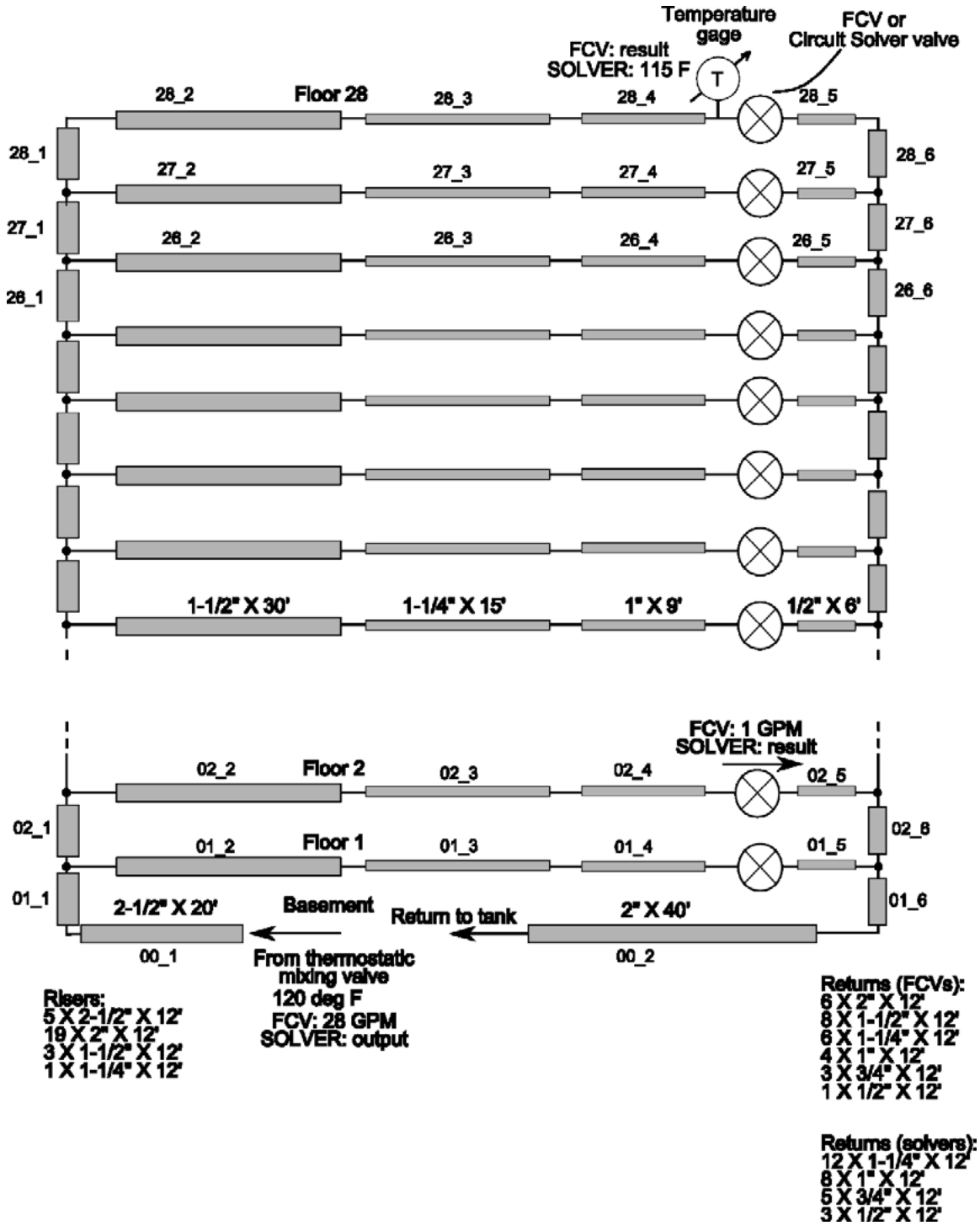
this study. That is, the SOLVER system may be even more beneficial relative to the FCV system for the more practical medium to high hot water usage conditions.

All the above arguments are hypothetical and should be checked out with the simulation tools developed for the present study.

References

1. ASHRAE Standard 90.1-2010 page 69, Table 6.8.3A "Minimum Pipe Insulation Thickness – Heating and Hot Water Systems (Steam, Steam Condensate, Hot Water Heating and Domestic Water Systems)"

2. Incropera, F. P, and D. P. DeWitt, "Fundamentals of Mass and Heat Transfer," 2nd edition, John Wiley & Sons, 1985



Insulation schedule: Use standard fiberglass insulation on all pipes, 1" thickness for pipes under 1-1/2" diameter, and 1-1/2" thickness for pipes 1-1/2" diameter and above

Figure 1. Schematic of the modeled systems

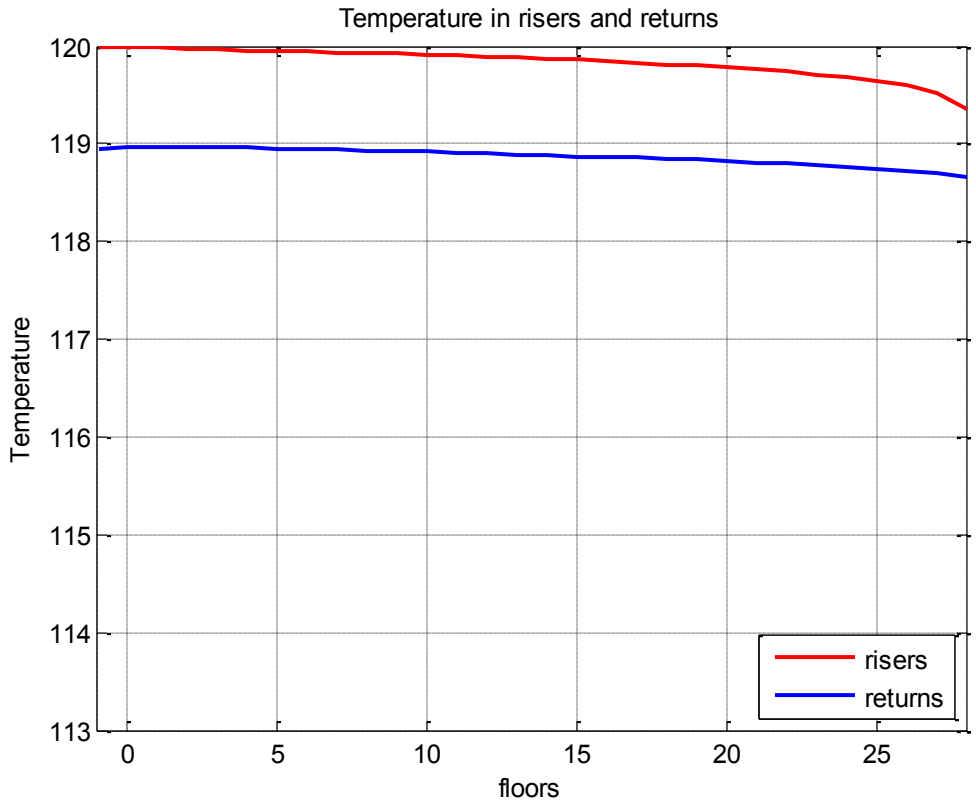


Figure 2. Temperature as function of the floor in risers and returns - FCV problem

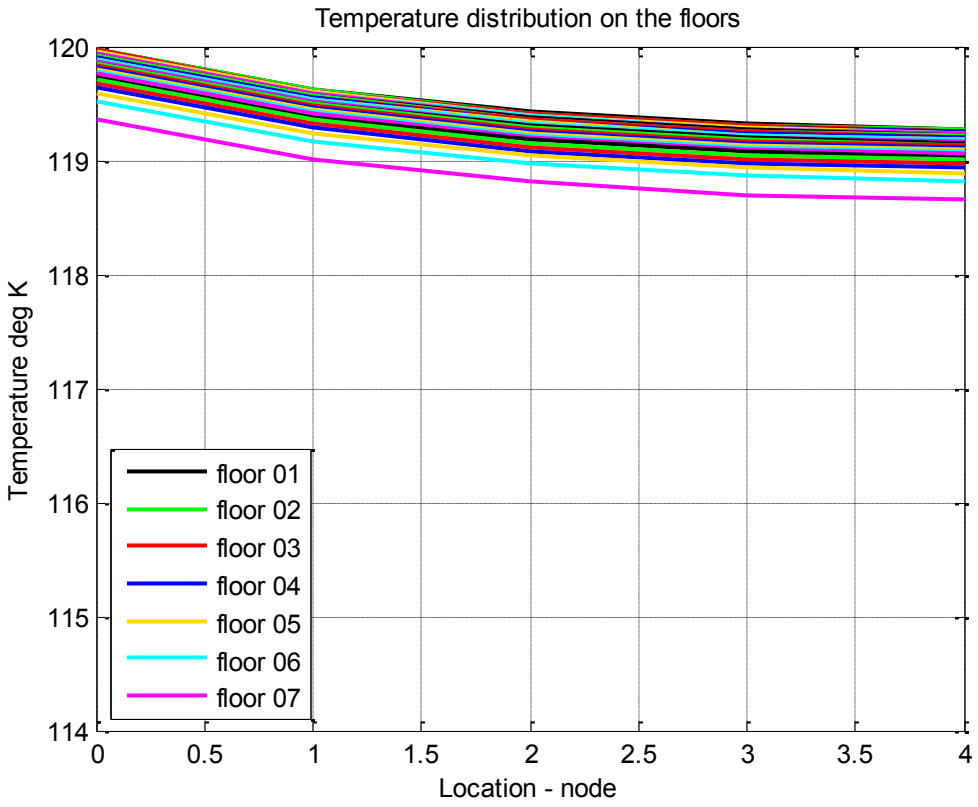


Figure 3. Temperature distribution on the floors as a function of node – FCV problem (nodes are locations between branches – node 3 is valve location Legend colors cycle for every 7 floors – only first 7 shown)

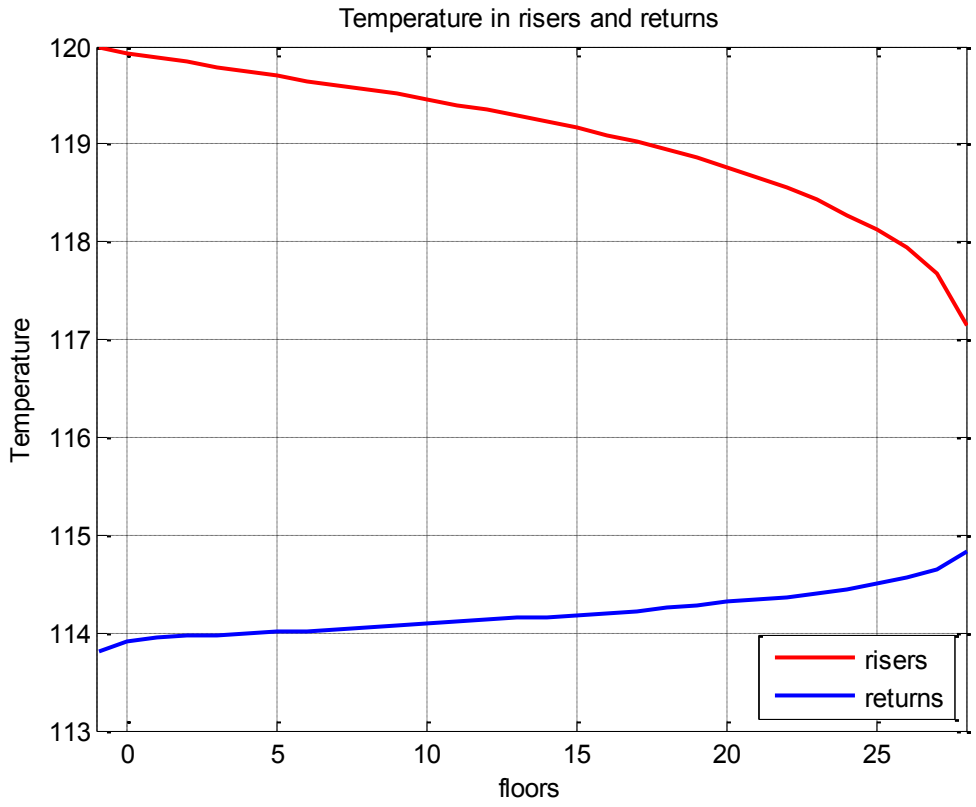


Figure 4. Temperature as function of the floor in risers and returns - SOLVER problem

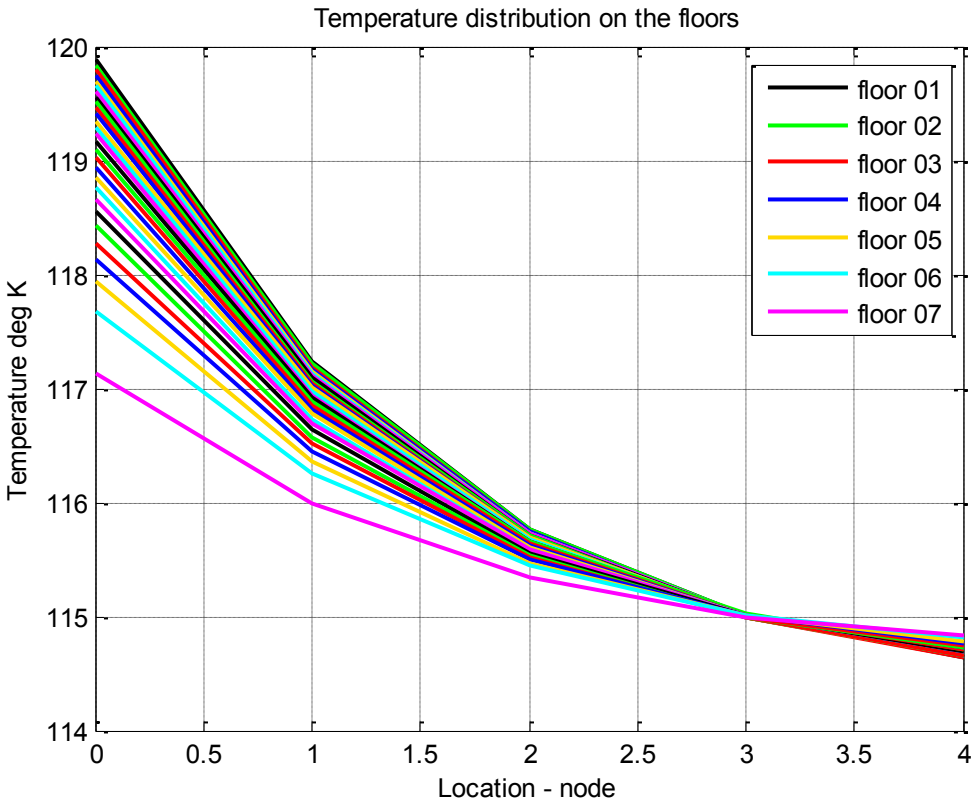


Figure 5. Temperature distribution on the floors as a function of node – SOLVER problem (nodes are locations between branches – node 3 is valve location Legend colors cycle for every 7 floors – only first 7 shown)

1.0000	119.3167
2.0000	119.3096
3.0000	119.3022
4.0000	119.2945
5.0000	119.2865
6.0000	119.2793
7.0000	119.2717
8.0000	119.2638
9.0000	119.2555
10.0000	119.2467
11.0000	119.2375
12.0000	119.2277
13.0000	119.2173
14.0000	119.2062
15.0000	119.1943
16.0000	119.1816
17.0000	119.1677
18.0000	119.1527
19.0000	119.1361
20.0000	119.1176
21.0000	119.0969
22.0000	119.0733
23.0000	119.0457
24.0000	119.0126
25.0000	118.9779
26.0000	118.9316
27.0000	118.8623
28.0000	118.7015

Table 1. Valve upstream temperatures (degF) on each floor for the FCV problem

1.0000	0.1271
2.0000	0.1284
3.0000	0.1293
4.0000	0.1305
5.0000	0.1319
6.0000	0.1332
7.0000	0.1345
8.0000	0.1358
9.0000	0.1371
10.0000	0.1384
11.0000	0.1406
12.0000	0.1424
13.0000	0.1442
14.0000	0.1460
15.0000	0.1484
16.0000	0.1512
17.0000	0.1534
18.0000	0.1565
19.0000	0.1597
20.0000	0.1632
21.0000	0.1677
22.0000	0.1727
23.0000	0.1785
24.0000	0.1864
25.0000	0.1956
26.0000	0.2081
27.0000	0.2288
28.0000	0.2832

Table 2. Flow rates (GPM) on each floor for the SOLVER problem

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_00_1:	120.00	119.99	1.904	162.93
_00_2:	118.97	118.95	2.935	275.65
_01_1:	119.99	119.98	1.904	97.73
_01_2:	119.98	119.63	0.182	176.64
_01_3:	119.63	119.42	0.258	102.24
_01_4:	119.42	119.32	0.393	53.79
_01_5:	119.32	119.28	1.391	20.85
_01_6:	118.97	118.97	2.935	82.72
_02_1:	119.98	119.97	1.836	97.72
_02_2:	119.97	119.62	0.182	176.61
_02_3:	119.62	119.42	0.258	102.22
_02_4:	119.42	119.31	0.393	53.78
_02_5:	119.31	119.27	1.391	20.85
_02_6:	118.97	118.96	2.830	82.71
_03_1:	119.97	119.97	1.768	97.70
_03_2:	119.97	119.61	0.182	176.58
_03_3:	119.61	119.41	0.258	102.21
_03_4:	119.41	119.30	0.393	53.77
_03_5:	119.30	119.26	1.391	20.85
_03_6:	118.96	118.96	2.726	82.70
_04_1:	119.97	119.96	1.700	97.68
_04_2:	119.96	119.61	0.182	176.55
_04_3:	119.61	119.40	0.258	102.19
_04_4:	119.40	119.29	0.393	53.76
_04_5:	119.29	119.25	1.391	20.84
_04_6:	118.96	118.95	2.621	82.68
_05_1:	119.96	119.95	1.632	97.66
_05_2:	119.95	119.60	0.182	176.52
_05_3:	119.60	119.39	0.258	102.17
_05_4:	119.39	119.29	0.393	53.75
_05_5:	119.29	119.24	1.391	20.84
_05_6:	118.95	118.95	2.516	82.67
_06_1:	119.95	119.94	2.412	84.55
_06_2:	119.94	119.59	0.182	176.49
_06_3:	119.59	119.39	0.258	102.15
_06_4:	119.39	119.28	0.393	53.74
_06_5:	119.28	119.24	1.391	20.84
_06_6:	118.95	118.94	2.411	82.66

Table 3. Detailed output for the FCV problem

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_07_1:	119.94	119.94	2.307	84.53
_07_2:	119.94	119.58	0.182	176.46
_07_3:	119.58	119.38	0.258	102.13
_07_4:	119.38	119.27	0.393	53.74
_07_5:	119.27	119.23	1.391	20.83
_07_6:	118.94	118.93	4.012	69.58
_08_1:	119.94	119.93	2.202	84.52
_08_2:	119.93	119.58	0.182	176.43
_08_3:	119.58	119.37	0.258	102.12
_08_4:	119.37	119.26	0.393	53.73
_08_5:	119.26	119.22	1.391	20.83
_08_6:	118.93	118.93	3.830	69.56
_09_1:	119.93	119.92	2.097	84.50
_09_2:	119.92	119.57	0.182	176.40
_09_3:	119.57	119.36	0.258	102.10
_09_4:	119.36	119.26	0.393	53.72
_09_5:	119.26	119.21	1.391	20.82
_09_6:	118.93	118.92	3.647	69.55
_10_1:	119.92	119.91	1.992	84.48
_10_2:	119.91	119.56	0.182	176.36
_10_3:	119.56	119.35	0.258	102.08
_10_4:	119.35	119.25	0.393	53.71
_10_5:	119.25	119.21	1.391	20.82
_10_6:	118.92	118.91	3.465	69.54
_11_1:	119.91	119.90	1.887	84.46
_11_2:	119.90	119.55	0.182	176.32
_11_3:	119.55	119.34	0.258	102.05
_11_4:	119.34	119.24	0.393	53.69
_11_5:	119.24	119.20	1.391	20.82
_11_6:	118.91	118.90	3.282	69.52
_12_1:	119.90	119.89	1.783	84.44
_12_2:	119.89	119.54	0.182	176.28
_12_3:	119.54	119.33	0.258	102.03
_12_4:	119.33	119.23	0.393	53.68
_12_5:	119.23	119.19	1.391	20.81
_12_6:	118.90	118.89	3.100	69.50
_13_1:	119.89	119.88	1.678	84.42
_13_2:	119.88	119.53	0.182	176.24

Table 3 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_13_3:	119.53	119.32	0.258	102.01
_13_4:	119.32	119.22	0.393	53.67
_13_5:	119.22	119.18	1.391	20.81
_13_6:	118.89	118.88	2.918	69.49
_14_1:	119.88	119.87	1.573	84.39
_14_2:	119.87	119.52	0.182	176.20
_14_3:	119.52	119.31	0.258	101.98
_14_4:	119.31	119.21	0.393	53.66
_14_5:	119.21	119.16	1.391	20.80
_14_6:	118.88	118.87	2.735	69.47
_15_1:	119.87	119.86	1.468	84.37
_15_2:	119.86	119.51	0.182	176.15
_15_3:	119.51	119.30	0.258	101.95
_15_4:	119.30	119.19	0.393	53.64
_15_5:	119.19	119.15	1.391	20.80
_15_6:	118.87	118.86	3.614	80.90
_16_1:	119.86	119.84	1.363	84.34
_16_2:	119.84	119.49	0.182	176.10
_16_3:	119.49	119.29	0.258	101.92
_16_4:	119.29	119.18	0.393	53.63
_16_5:	119.18	119.14	1.391	20.79
_16_6:	118.86	118.85	3.356	80.88
_17_1:	119.84	119.83	1.258	84.31
_17_2:	119.83	119.48	0.182	176.05
_17_3:	119.48	119.27	0.258	101.89
_17_4:	119.27	119.17	0.393	53.61
_17_5:	119.17	119.13	1.391	20.78
_17_6:	118.86	118.84	3.097	80.86
_18_1:	119.83	119.82	1.153	84.28
_18_2:	119.82	119.46	0.182	175.99
_18_3:	119.46	119.26	0.258	101.86
_18_4:	119.26	119.15	0.393	53.59
_18_5:	119.15	119.11	1.391	20.78
_18_6:	118.85	118.83	2.839	80.83
_19_1:	119.82	119.80	1.049	84.24
_19_2:	119.80	119.45	0.182	175.92
_19_3:	119.45	119.24	0.258	101.82
_19_4:	119.24	119.14	0.393	53.57

Table 3 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_19_5:	119.14	119.09	1.391	20.77
_19_6:	118.83	118.82	2.581	80.81
_20_1:	119.80	119.78	0.944	84.20
_20_2:	119.78	119.43	0.182	175.85
_20_3:	119.43	119.22	0.258	101.78
_20_4:	119.22	119.12	0.393	53.55
_20_5:	119.12	119.08	1.391	20.76
_20_6:	118.82	118.81	2.323	80.78
_21_1:	119.78	119.76	0.839	84.15
_21_2:	119.76	119.41	0.182	175.76
_21_3:	119.41	119.20	0.258	101.73
_21_4:	119.20	119.10	0.393	53.52
_21_5:	119.10	119.06	1.391	20.75
_21_6:	118.81	118.79	3.145	70.99
_22_1:	119.76	119.73	0.734	84.10
_22_2:	119.73	119.38	0.182	175.67
_22_3:	119.38	119.18	0.258	101.67
_22_4:	119.18	119.07	0.393	53.49
_22_5:	119.07	119.03	1.391	20.74
_22_6:	118.80	118.78	2.752	70.96
_23_1:	119.73	119.71	0.629	84.03
_23_2:	119.71	119.36	0.182	175.56
_23_3:	119.36	119.15	0.258	101.61
_23_4:	119.15	119.05	0.393	53.46
_23_5:	119.05	119.00	1.391	20.73
_23_6:	118.78	118.76	2.359	70.92
_24_1:	119.71	119.67	0.524	83.95
_24_2:	119.67	119.32	0.182	175.43
_24_3:	119.32	119.12	0.258	101.53
_24_4:	119.12	119.01	0.393	53.42
_24_5:	119.01	118.97	1.391	20.71
_24_6:	118.76	118.73	1.966	70.89
_25_1:	119.67	119.64	0.730	70.63
_25_2:	119.64	119.29	0.182	175.29
_25_3:	119.29	119.08	0.258	101.45
_25_4:	119.08	118.98	0.393	53.38
_25_5:	118.98	118.94	1.391	20.69
_25_6:	118.74	118.71	2.681	60.86

Table 3 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_26_1:	119.64	119.59	0.547	70.54
_26_2:	119.59	119.24	0.182	175.10
_26_3:	119.24	119.04	0.258	101.35
_26_4:	119.04	118.93	0.393	53.32
_26_5:	118.93	118.89	1.391	20.67
_26_6:	118.72	118.68	2.011	60.81
_27_1:	119.59	119.52	0.365	70.40
_27_2:	119.52	119.17	0.182	174.83
_27_3:	119.17	118.97	0.258	101.19
_27_4:	118.97	118.86	0.393	53.24
_27_5:	118.86	118.82	1.391	20.64
_27_6:	118.69	118.63	1.340	60.73
_28_1:	119.52	119.36	0.258	81.63
_28_2:	119.36	119.01	0.182	174.19
_28_3:	119.01	118.81	0.258	100.82
_28_4:	118.81	118.70	0.393	53.04
_28_5:	118.70	118.66	1.391	20.56
_28_6:	118.66	118.56	1.391	50.28

Table 3 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_00_1:	120.00	119.93	0.303	162.47
_00_2:	113.92	113.81	1.148	243.30
_01_1:	119.93	119.88	0.303	97.35
_01_2:	119.88	117.23	0.023	168.54
_01_3:	117.23	115.76	0.033	93.50
_01_4:	115.76	115.00	0.050	48.28
_01_5:	115.00	114.65	0.177	22.83
_01_6:	113.95	113.92	1.148	71.74
_02_1:	119.88	119.84	0.294	97.25
_02_2:	119.84	117.22	0.023	168.45
_02_3:	117.22	115.76	0.033	93.49
_02_4:	115.76	115.01	0.050	48.28
_02_5:	115.01	114.65	0.178	22.83
_02_6:	113.96	113.93	1.115	71.76
_03_1:	119.84	119.79	0.285	97.14
_03_2:	119.79	117.19	0.024	168.33
_03_3:	117.19	115.74	0.033	93.46
_03_4:	115.74	115.00	0.051	48.27
_03_5:	115.00	114.65	0.180	22.83
_03_6:	113.98	113.94	1.082	71.78
_04_1:	119.79	119.74	0.277	97.04
_04_2:	119.74	117.17	0.024	168.23
_04_3:	117.17	115.74	0.034	93.44
_04_4:	115.74	115.00	0.051	48.28
_04_5:	115.00	114.65	0.181	22.83
_04_6:	113.99	113.95	1.049	71.80
_05_1:	119.74	119.70	0.268	96.92
_05_2:	119.70	117.15	0.024	168.12
_05_3:	117.15	115.73	0.034	93.43
_05_4:	115.73	115.00	0.052	48.28
_05_5:	115.00	114.65	0.183	22.83
_05_6:	114.00	113.97	1.015	71.83
_06_1:	119.70	119.65	0.399	83.89
_06_2:	119.65	117.13	0.024	168.03
_06_3:	117.13	115.73	0.034	93.42
_06_4:	115.73	115.00	0.052	48.28
_06_5:	115.00	114.66	0.185	22.83
_06_6:	114.02	113.98	0.981	71.85

Table 4. Detailed output for the SOLVER problem

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_07_1:	119.65	119.61	0.385	83.79
_07_2:	119.61	117.11	0.025	167.93
_07_3:	117.11	115.72	0.035	93.41
_07_4:	115.72	115.00	0.053	48.29
_07_5:	115.00	114.66	0.187	22.84
_07_6:	114.04	114.00	0.947	71.87
_08_1:	119.61	119.56	0.371	83.70
_08_2:	119.56	117.09	0.025	167.82
_08_3:	117.09	115.71	0.035	93.39
_08_4:	115.71	115.00	0.053	48.29
_08_5:	115.00	114.67	0.189	22.84
_08_6:	114.05	114.01	0.912	71.90
_09_1:	119.56	119.51	0.357	83.61
_09_2:	119.51	117.06	0.025	167.71
_09_3:	117.06	115.70	0.035	93.37
_09_4:	115.70	115.00	0.054	48.28
_09_5:	115.00	114.67	0.190	22.84
_09_6:	114.07	114.03	0.877	71.93
_10_1:	119.51	119.46	0.342	83.50
_10_2:	119.46	117.04	0.025	167.59
_10_3:	117.04	115.69	0.036	93.34
_10_4:	115.69	114.99	0.054	48.28
_10_5:	114.99	114.66	0.192	22.84
_10_6:	114.09	114.04	0.842	71.96
_11_1:	119.46	119.41	0.328	83.40
_11_2:	119.41	117.02	0.026	167.50
_11_3:	117.02	115.70	0.036	93.36
_11_4:	115.70	115.01	0.055	48.30
_11_5:	115.01	114.69	0.195	22.85
_11_6:	114.11	114.06	0.806	71.99
_12_1:	119.41	119.35	0.313	83.29
_12_2:	119.35	117.00	0.026	167.38
_12_3:	117.00	115.69	0.037	93.34
_12_4:	115.69	115.01	0.056	48.31
_12_5:	115.01	114.69	0.198	22.86
_12_6:	114.13	114.08	0.770	72.02
_13_1:	119.35	119.29	0.298	83.17
_13_2:	119.29	116.97	0.026	167.25

Table 4 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_13_3:	116.97	115.68	0.037	93.31
_13_4:	115.68	115.01	0.057	48.31
_13_5:	115.01	114.69	0.200	22.86
_13_6:	114.15	114.10	1.117	63.36
_14_1:	119.29	119.23	0.283	83.05
_14_2:	119.23	116.94	0.027	167.10
_14_3:	116.94	115.66	0.038	93.28
_14_4:	115.66	115.00	0.057	48.30
_14_5:	115.00	114.69	0.203	22.86
_14_6:	114.16	114.12	1.060	63.38
_15_1:	119.23	119.16	0.268	82.92
_15_2:	119.16	116.92	0.027	166.97
_15_3:	116.92	115.66	0.038	93.27
_15_4:	115.66	115.01	0.058	48.31
_15_5:	115.01	114.70	0.206	22.86
_15_6:	114.18	114.13	1.003	63.40
_16_1:	119.16	119.10	0.252	82.78
_16_2:	119.10	116.89	0.028	166.84
_16_3:	116.89	115.66	0.039	93.27
_16_4:	115.66	115.02	0.059	48.33
_16_5:	115.02	114.72	0.210	22.87
_16_6:	114.20	114.15	0.944	63.43
_17_1:	119.10	119.02	0.236	82.63
_17_2:	119.02	116.85	0.028	166.66
_17_3:	116.85	115.64	0.040	93.22
_17_4:	115.64	115.01	0.060	48.32
_17_5:	115.01	114.71	0.213	22.87
_17_6:	114.23	114.17	0.885	63.46
_18_1:	119.02	118.94	0.220	82.47
_18_2:	118.94	116.82	0.029	166.50
_18_3:	116.82	115.63	0.040	93.21
_18_4:	115.63	115.01	0.061	48.32
_18_5:	115.01	114.72	0.217	22.87
_18_6:	114.25	114.19	0.825	63.49
_19_1:	118.94	118.86	0.204	82.30
_19_2:	118.86	116.78	0.029	166.31
_19_3:	116.78	115.61	0.041	93.17
_19_4:	115.61	115.01	0.063	48.32

Table 4 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_19_5:	115.01	114.72	0.222	22.88
_19_6:	114.28	114.21	0.763	63.52
_20_1:	118.86	118.77	0.187	82.11
_20_2:	118.77	116.73	0.030	166.09
_20_3:	116.73	115.59	0.042	93.13
_20_4:	115.59	115.00	0.064	48.32
_20_5:	115.00	114.72	0.227	22.88
_20_6:	114.31	114.24	0.701	63.56
_21_1:	118.77	118.67	0.170	81.91
_21_2:	118.67	116.69	0.031	165.88
_21_3:	116.69	115.58	0.043	93.10
_21_4:	115.58	115.00	0.066	48.33
_21_5:	115.00	114.73	0.233	22.88
_21_6:	114.34	114.27	1.085	54.66
_22_1:	118.67	118.55	0.152	81.67
_22_2:	118.55	116.64	0.031	165.63
_22_3:	116.64	115.56	0.045	93.06
_22_4:	115.56	115.00	0.068	48.33
_22_5:	115.00	114.74	0.240	22.89
_22_6:	114.37	114.29	0.973	54.69
_23_1:	118.55	118.43	0.134	81.40
_23_2:	118.43	116.58	0.033	165.34
_23_3:	116.58	115.53	0.046	93.00
_23_4:	115.53	114.99	0.070	48.33
_23_5:	114.99	114.74	0.248	22.89
_23_6:	114.40	114.32	0.857	54.71
_24_1:	118.43	118.28	0.116	81.09
_24_2:	118.28	116.51	0.034	165.03
_24_3:	116.51	115.51	0.048	92.96
_24_4:	115.51	115.00	0.073	48.34
_24_5:	115.00	114.75	0.259	22.90
_24_6:	114.45	114.35	0.738	54.76
_25_1:	118.28	118.13	0.167	68.11
_25_2:	118.13	116.45	0.036	164.72
_25_3:	116.45	115.50	0.050	92.94
_25_4:	115.50	115.00	0.077	48.36
_25_5:	115.00	114.77	0.272	22.91
_25_6:	114.51	114.39	0.613	54.80

Table 4 (continued)

Branch ID	T upst deg F	T downst deg F	Exit Vel. ft/sec	Heat Tr rate BTU/hr
_26_1:	118.13	117.94	0.131	67.78
_26_2:	117.94	116.37	0.038	164.32
_26_3:	116.37	115.47	0.054	92.89
_26_4:	115.47	115.01	0.082	48.37
_26_5:	115.01	114.79	0.289	22.92
_26_6:	114.56	114.43	1.000	45.52
_27_1:	117.94	117.68	0.093	67.30
_27_2:	117.68	116.25	0.042	163.77
_27_3:	116.25	115.44	0.059	92.82
_27_4:	115.44	115.02	0.090	48.40
_27_5:	115.02	114.82	0.318	22.94
_27_6:	114.65	114.47	0.711	45.56
_28_1:	117.68	117.14	0.073	77.29
_28_2:	117.14	115.99	0.052	162.56
_28_3:	115.99	115.33	0.073	92.62
_28_4:	115.33	114.99	0.111	48.40
_28_5:	114.99	114.83	0.393	22.95
_28_6:	114.83	114.51	0.393	45.62

Table 4 (continued)

APPENDIX A

List of the programs

branch.m

```
function [p,h,rho,v,ve,msg,pthqd]=branch(pthqu,qm,tamb,linevec,contvec)
%   from waterline03.c, detail ktherm, mu vs. T lookup functions

%  Inputs:
%  pthqu vector:
%   pu................upstream volume pressure
%   tu................upstream volume temperature
%   hu................upstream volume specific enthalpy
%   qqu...............dummy, just so that output #4 of one line can be connected to input port #0 of
another
%  qm................downstream mass flow rate
%  tamb..............Ambient temperature over the insulation
%  linevec vector:
%   length............Line length [feet]
%   diam..............Line diameter [inches]
%   diama.............Outer diameter of tube [inches]
%   thins.............Thickness of insulation  [inch]
%   nseg..............number of line segments
%   kline.............Pipe material thermal conductivity
%   kinsul............Insulation material thermal conductivity
%  contvec vector:
%   relerr............Relative error to get within at end of iterations
%   itmx..............Lookup iteration max lengths
%   dgns..............1: print diagnostic messages, 0: do not print diagnostic messages

%   Output signals:
%   p(nseg)...........vector of pressures in segments
%   h(nseg+1).........vector of enthalpies in segments
```

```
%   rho(nseg+1).......vector of densities in segments
%   v(nseg+1).........vector of velocities in segments
%   ve................exit velocity
%   msg...............number of diagnostic messages
%   pthqd.............vector of exit pressure, temperature, specific enthalpy, and total heat transfer to
air

pu     = pthqu(1);
tu     = pthqu(2);
hu     = pthqu(3);
qqu    = pthqu(4);
length = linevec(1)*0.3048;   %convert from feet to meters
diam   = linevec(2)*25.4e-3;  %convert from inches to meters
diama  = linevec(3)*25.4e-3;  %convert from inches to meters
thins  = linevec(4)*25.4e-3;  %convert from inches to meters
nseg   = linevec(5);
kline  = linevec(6);
kinsul = linevec(7);
relerr = contvec(1);
itmx   = contvec(2);
dgns   = contvec(3);

msg    = 0.0;
area   = diam*diam/4.0*3.1415926;
lseg   = length/nseg;
volseg = lseg*area;
ai     = lseg*diam*3.1415926;     %inside tube surface area per line segment
aa     = lseg*diama*3.1415926;    %outside tube surface area per line segment
diami  = diama+2.*thins;          %outside diameter of insulation

rho=zeros(1,41);
v=zeros(1,41);
p=zeros(1,41);
t=zeros(1,41);
h=zeros(1,41);
qat=zeros(1,41);
```

```
p(1)   = pu;
h(1)   = hu;
mdot   = qm;
t(1)   = temp_h2o(h(1));
rho(1) = rho_h2o(t(1));

%Main Sweep Starts.  Make geometry and heat transfer model dependent changes here
qatot = 0.0;
for i=1:1:nseg

    if (i==1)
       v(1) = mdot/rho(1)/area;
    end
    mu = mu_h2o(t(i));
    ktherm = ktherm_h2o(t(i));
    cp = cp_h2o(t(i));

    red = rho(i)*abs(v(i))*diam/mu;
    if (red < 10)
        fricfact = 64/10.;
    else
        if (red > 2300)
            fricfact = 0.316/sqrt(sqrt(red));
        else
            fricfact = 64/red;
        end
    end
    dpfric = fricfact*lseg/diam*rho(i)*abs(v(i))*v(i)/2.0;

    prandtl = cp * mu / ktherm;
    if (tamb > t(i))
        npr = 0.4;
    else
        npr = 0.3;
    end
    %here comes Eq.8.58 in Incropera
    nud = 0.023*red^0.8*prandtl^npr;
```

```
    hbar = nud*ktherm/diam;

    qpa1 = 0.0;   %low estimate of heat flow rate
    t1 = t(i);
    qpa2 = 2.0*3.1415926*lseg*kinsul*(t(i)-tamb)/log(diami/diama);  %high estimate of heat flow rate,
Incropera 3.26
    t_id = t(i)-qpa2/hbar/ai;  %qpa2 = hbar*ai*(t[i]-t_id);
    tod = t_id-(qpa2*log(diama/diam)/(2.0*3.1415926*lseg*kline));  %from Incropera 3.26
    todi= tod-(qpa2*log(diami/diama)/(2.0*3.1415926*lseg*kinsul));
    t2= todi;

    qpa3 = (qpa1+qpa2)/2.0;
    t_id = t(i)-qpa3/hbar/ai;  %qpa2 = hbar*ai*(t[i]-t_id);
    tod = t_id-(qpa3*log(diama/diam)/(2.0*3.1415926*lseg*kline));
    todi= tod-(qpa3*log(diami/diama)/(2.0*3.1415926*lseg*kinsul));
    t3= todi;

    j = 0;
    while((abs(t3-tamb) > 1e-3) && (j<itmx+1))
        if ((t3-tamb) > 0.0)
            qpa1 = qpa3;
            t1 = t3;
        else
            qpa2 = qpa3;
            t2 = t3;
        end
        qpa3 = (qpa1+qpa2)/2.0;
        t_id = t(i)-qpa3/hbar/ai;  %qpa2 = hbar*ai*(t[i]-t_id);
        tod = t_id-(qpa3*log(diama/diam)/(2.0*3.1415926*lseg*kline));
        todi= tod-(qpa3*log(diami/diama)/(2.0*3.1415926*lseg*kinsul));
        t3= todi;
        j = j+1;
    end
    %end Loop to iterate on tube wall heat transfer, qp

    if ((j==itmx+1)&&(dgns > 0))
       display('waterline03.c: Did not converge on heat transfer rate - move on with final estimate');
```

```
       display('i,t3-tamb,qpa3');
       [i,t3-tamb,qpa3]
    end


    qat(i) = qpa3;
    qatot = qatot + qat(i);   %summ up all heat flow rates

    h(i+1) = h(i) - qat(i)/mdot;
    t(i+1) = temp_h2o(h(i+1));
    p(i+1) = p(i) - dpfric;
    rho(i+1) = rho_h2o(t(i+1));
    v(i+1) = mdot/rho(i+1)/area;
    if (  ((t(i+1)-tamb)*(t(i)-tamb)<0.0) && (abs(t(i+1)-tamb)>1.0) )
        display('R134a temperature crossed over air temperature. Line segment too long in waterline03');
        display('t(i+1),tamb');
        [t(i+1),tamb]
    end

end
pthqd = [p(nseg+1),t(nseg+1),h(nseg+1),qatot];
ve = v(nseg+1);



function rho=rho_h2o(tempr)
    %interpolate water density based on temperature as input
    %lookup table generated with XSteam('rho_pT',5,tvec[i]-273.16) that is, all for 5 bar
    tvec = [ 273.16, 278.16, 283.16, 288.16, 293.16, 298.16, 303.16, 308.16, 313.16, 318.16,...
                             323.16, 328.16, 333.16, 338.16, 343.16, 348.16, 353.16, 358.16, 363.16,
368.16]; %tempr K
    rhovec=[1000.05,1000.16, 999.89, 999.29, 998.39, 997.23, 995.83, 994.21, 992.40, 990.40,...
                             988.22, 985.88, 983.38, 980.74, 977.95, 975.03, 971.98, 968.80, 965.50,
962.08]; %density, kg/m3
    n = 20;  %set to length of tvec/muvec
    mut = 0;
```

```
    i1 = n - 1;
    for i=2:1:n
       if ((tempr <= tvec(i)) && (mut < 0.5))
          i1 = i-1;
          mut = 1.0;
          break;
       end
    end
    rho = (tempr - tvec(i1))/(tvec(i1+1) - tvec(i1)) * (rhovec(i1+1) - rhovec(i1)) + rhovec(i1);

function mu = mu_h2o(tempr)
    %interpolate water dynamic viscosity based on temperature as input
    %lookup table generated with XSteam('my_pT',8,tvec[i]-273.16) that is, all for 8 bar
    tvec = [ 273.16, 278.16, 283.16, 288.16, 293.16, 298.16, 303.16, 308.16, 313.16, 318.16,...
                     323.16, 328.16, 333.16, 338.16, 343.16, 348.16, 353.16, 358.16, 363.16, 368.16];
%tempr K
    muvec =[ 1.789,   1.517,  1.305,  1.137,  1.001,  0.890,  0.797,  0.719,  0.653,  0.596,...
                      0.547,  0.504,  0.467,  0.433,  0.404,  0.378,  0.355,  0.334,  0.315,  0.297]*1e-3;
%viscosity Pa*s
    n = 20;  %set to length of tvec/muvec
    mut = 0;
    i1 = n - 1;
    for i=2:1:n
       if ((tempr <= tvec(i)) && (mut < 0.5))
          i1 = i-1;
          mut = 1.0;
          break;
       end
    end
    mu = (tempr - tvec(i1))/(tvec(i1+1) - tvec(i1)) * (muvec(i1+1) - muvec(i1)) + muvec(i1);

function ktherm = ktherm_h2o(tempr)
    %interpolate water thermal conductivity based on temperature as input
    %lookup table generated with XSteam('tc_pT',8,tvec[i]-273.16) that is, all for 8 bar
    tvec = [ 273.16, 278.16, 283.16, 288.16, 293.16, 298.16, 303.16, 308.16, 313.16, 318.16,...
                     323.16, 328.16, 333.16, 338.16, 343.16, 348.16, 353.16, 358.16, 363.16, 368.16];
%tempr K
```

```
    kvec = [ 0.5625, 0.5727, 0.5824, 0.5914, 0.5999, 0.6079, 0.6154, 0.6224, 0.6290, 0.6351,...
                     0.6409, 0.6462, 0.6512, 0.6558, 0.6600, 0.6638, 0.6674, 0.6705, 0.6734, 0.6759];
%W/(mK)
    n = 20;  %set to length of tvec/muvec
    mut = 0;
    i1 = n - 1;
    for i=2:1:n
       if ((tempr <= tvec(i)) && (mut < 0.5))
          i1 = i-1;
          mut = 1.0;
          break;
       end
    end
    ktherm = (tempr - tvec(i1))/(tvec(i1+1) - tvec(i1)) * (kvec(i1+1) - kvec(i1)) + kvec(i1);


function cp = cp_h2o(tempr)
    %constant is sufficient with temperatue/pressure range
    cp = 4180.;


function temp = temp_h2o(enth)
    %interpolate water temperature based on enthalpy as input
    %the one line approximation at the end is totally adequate
    temp = enth/4180.+273.16;
```

fcvsystem.m

```
%for SETTER circuit
%Lines are all for Type L domestic water copper tube

%Generic initialization
clear all;
relerr = 1e-4;      %relative error in iterations
itmx = 20;          %maximum number of iterations in any loop
dgns = 1.0;         %display message: 1.0, do not display: 0.0
contvec=[relerr,itmx,dgns];
kline  = 400.;      %W/(m*K), copper, Incropera fig 2.5, line wall thermal conductivity
kinsul = 0.038;     %0.038 W/(m*K), fiberglass coated duct liner, Incropera Table A.3
tamb = 297.0489;    %degK, ambient temperature = 75deg F

%thermostatic mixing valve conditions
p_tmv = 15e5;       %downstream pressure - not relevant
t_tmv = 322.049;    %downstream temperature = 120degF
h_tmv = 204356.;    %based on t_tmv
pthq_00_0=[p_tmv,t_tmv,h_tmv,0.0];  %provides upstream input for line after TMV

%%%%%%%%%% FLOW RATES %%%%%%%%%%%
for i=1:1:28
   qm(i) = 1.0*3.7854e-3/60.*1000.; %kg/sec, 1 gallons/minute flow rate in valve on floor 01
end
qm=qm';

%%%%%%%%%% FLOORS %%%%%%%%%%%%%%%
%             length  id     od   th-ins  n  W/(mK) W/(mK)
linevec_99_2=[ 30., 1.505, 1.625, 1.500, 30, kline, kinsul];  %nom 1 1/2"
linevec_99_3=[ 15., 1.265, 1.375, 1.000, 15, kline, kinsul];  %nom 1 1/4"
linevec_99_4=[  9., 1.025, 1.125, 1.000,  9, kline, kinsul];  %nom 1"
linevec_99_5=[  6., 0.545, 0.625, 1.000,  6, kline, kinsul];  %nom 1/2"

%%%%%%%% RISERS %%%%%%%%%%%%%%%%%%%
%             length  id     od   th-ins  n  W/(mK) W/(mK)
```

```
linevec_00_1=[ 20., 2.465, 2.625, 1.500, 20, kline, kinsul];  %nom 2 1/2"
linevec_01_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_02_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_03_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_04_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_05_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_06_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_07_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_08_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_09_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_10_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_11_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_12_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_13_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_14_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_15_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_16_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_17_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_18_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_19_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_20_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_21_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_22_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_23_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_24_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_25_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_26_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_27_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_28_1=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"

%%%%%%%%%%%%%%% RETURNS %%%%%%%%%%%%%%%%%%%%
%             length  id     od   th-ins  n  W/(mK) W/(mK)
linevec_00_2=[ 40., 1.985, 2.125, 1.500, 40, kline, kinsul];  %nom 2"
linevec_01_6=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_02_6=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_03_6=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_04_6=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
```

```
linevec_05_6=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_06_6=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_07_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_08_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_09_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_10_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_11_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_12_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_13_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_14_6=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_15_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_16_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_17_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_18_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_19_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_20_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_21_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_22_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_23_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_24_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_25_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_26_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_27_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_28_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"

qmtot(28) = qm(28);
for i=27:-1:1
    qmtot(i)=qmtot(i+1)+qm(i);
end

[p,h,rho,v,ve_00_1,msg,pthq_00_1]=branch(pthq_00_0,qmtot(1),tamb,linevec_00_1,contvec);

[p,h,rho,v,ve_01_1,msg,pthq_01_1]=branch(pthq_00_1,qmtot(1),tamb,linevec_01_1,contvec);
[p,h,rho,v,ve_01_2,msg,pthq_01_2]=branch(pthq_01_1,   qm(1),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_01_3,msg,pthq_01_3]=branch(pthq_01_2,   qm(1),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_01_4,msg,pthq_01_4]=branch(pthq_01_3,   qm(1),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_01_5,msg,pthq_01_5]=branch(pthq_01_4,   qm(1),tamb,linevec_99_5,contvec);
```

```
[p,h,rho,v,ve_02_1,msg,pthq_02_1]=branch(pthq_01_1,qmtot(2),tamb,linevec_02_1,contvec);
[p,h,rho,v,ve_02_2,msg,pthq_02_2]=branch(pthq_02_1,   qm(2),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_02_3,msg,pthq_02_3]=branch(pthq_02_2,   qm(2),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_02_4,msg,pthq_02_4]=branch(pthq_02_3,   qm(2),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_02_5,msg,pthq_02_5]=branch(pthq_02_4,   qm(2),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_03_1,msg,pthq_03_1]=branch(pthq_02_1,qmtot(3),tamb,linevec_03_1,contvec);
[p,h,rho,v,ve_03_2,msg,pthq_03_2]=branch(pthq_03_1,   qm(3),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_03_3,msg,pthq_03_3]=branch(pthq_03_2,   qm(3),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_03_4,msg,pthq_03_4]=branch(pthq_03_3,   qm(3),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_03_5,msg,pthq_03_5]=branch(pthq_03_4,   qm(3),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_04_1,msg,pthq_04_1]=branch(pthq_03_1,qmtot(4),tamb,linevec_04_1,contvec);
[p,h,rho,v,ve_04_2,msg,pthq_04_2]=branch(pthq_04_1,   qm(4),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_04_3,msg,pthq_04_3]=branch(pthq_04_2,   qm(4),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_04_4,msg,pthq_04_4]=branch(pthq_04_3,   qm(4),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_04_5,msg,pthq_04_5]=branch(pthq_04_4,   qm(4),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_05_1,msg,pthq_05_1]=branch(pthq_04_1,qmtot(5),tamb,linevec_05_1,contvec);
[p,h,rho,v,ve_05_2,msg,pthq_05_2]=branch(pthq_05_1,   qm(5),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_05_3,msg,pthq_05_3]=branch(pthq_05_2,   qm(5),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_05_4,msg,pthq_05_4]=branch(pthq_05_3,   qm(5),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_05_5,msg,pthq_05_5]=branch(pthq_05_4,   qm(5),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_06_1,msg,pthq_06_1]=branch(pthq_05_1,qmtot(6),tamb,linevec_06_1,contvec);
[p,h,rho,v,ve_06_2,msg,pthq_06_2]=branch(pthq_06_1,   qm(6),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_06_3,msg,pthq_06_3]=branch(pthq_06_2,   qm(6),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_06_4,msg,pthq_06_4]=branch(pthq_06_3,   qm(6),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_06_5,msg,pthq_06_5]=branch(pthq_06_4,   qm(6),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_07_1,msg,pthq_07_1]=branch(pthq_06_1,qmtot(7),tamb,linevec_07_1,contvec);
[p,h,rho,v,ve_07_2,msg,pthq_07_2]=branch(pthq_07_1,   qm(7),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_07_3,msg,pthq_07_3]=branch(pthq_07_2,   qm(7),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_07_4,msg,pthq_07_4]=branch(pthq_07_3,   qm(7),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_07_5,msg,pthq_07_5]=branch(pthq_07_4,   qm(7),tamb,linevec_99_5,contvec);
```

```
[p,h,rho,v,ve_08_1,msg,pthq_08_1]=branch(pthq_07_1,qmtot(8),tamb,linevec_08_1,contvec);
[p,h,rho,v,ve_08_2,msg,pthq_08_2]=branch(pthq_08_1,   qm(8),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_08_3,msg,pthq_08_3]=branch(pthq_08_2,   qm(8),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_08_4,msg,pthq_08_4]=branch(pthq_08_3,   qm(8),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_08_5,msg,pthq_08_5]=branch(pthq_08_4,   qm(8),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_09_1,msg,pthq_09_1]=branch(pthq_08_1,qmtot(9),tamb,linevec_09_1,contvec);
[p,h,rho,v,ve_09_2,msg,pthq_09_2]=branch(pthq_09_1,   qm(9),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_09_3,msg,pthq_09_3]=branch(pthq_09_2,   qm(9),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_09_4,msg,pthq_09_4]=branch(pthq_09_3,   qm(9),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_09_5,msg,pthq_09_5]=branch(pthq_09_4,   qm(9),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_10_1,msg,pthq_10_1]=branch(pthq_09_1,qmtot(10),tamb,linevec_10_1,contvec);
[p,h,rho,v,ve_10_2,msg,pthq_10_2]=branch(pthq_10_1,   qm(10),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_10_3,msg,pthq_10_3]=branch(pthq_10_2,   qm(10),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_10_4,msg,pthq_10_4]=branch(pthq_10_3,   qm(10),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_10_5,msg,pthq_10_5]=branch(pthq_10_4,   qm(10),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_11_1,msg,pthq_11_1]=branch(pthq_10_1,qmtot(11),tamb,linevec_11_1,contvec);
[p,h,rho,v,ve_11_2,msg,pthq_11_2]=branch(pthq_11_1,   qm(11),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_11_3,msg,pthq_11_3]=branch(pthq_11_2,   qm(11),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_11_4,msg,pthq_11_4]=branch(pthq_11_3,   qm(11),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_11_5,msg,pthq_11_5]=branch(pthq_11_4,   qm(11),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_12_1,msg,pthq_12_1]=branch(pthq_11_1,qmtot(12),tamb,linevec_12_1,contvec);
[p,h,rho,v,ve_12_2,msg,pthq_12_2]=branch(pthq_12_1,   qm(12),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_12_3,msg,pthq_12_3]=branch(pthq_12_2,   qm(12),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_12_4,msg,pthq_12_4]=branch(pthq_12_3,   qm(12),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_12_5,msg,pthq_12_5]=branch(pthq_12_4,   qm(12),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_13_1,msg,pthq_13_1]=branch(pthq_12_1,qmtot(13),tamb,linevec_13_1,contvec);
[p,h,rho,v,ve_13_2,msg,pthq_13_2]=branch(pthq_13_1,   qm(13),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_13_3,msg,pthq_13_3]=branch(pthq_13_2,   qm(13),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_13_4,msg,pthq_13_4]=branch(pthq_13_3,   qm(13),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_13_5,msg,pthq_13_5]=branch(pthq_13_4,   qm(13),tamb,linevec_99_5,contvec);
```

```
[p,h,rho,v,ve_14_1,msg,pthq_14_1]=branch(pthq_13_1,qmtot(14),tamb,linevec_14_1,contvec);
[p,h,rho,v,ve_14_2,msg,pthq_14_2]=branch(pthq_14_1,   qm(14),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_14_3,msg,pthq_14_3]=branch(pthq_14_2,   qm(14),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_14_4,msg,pthq_14_4]=branch(pthq_14_3,   qm(14),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_14_5,msg,pthq_14_5]=branch(pthq_14_4,   qm(14),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_15_1,msg,pthq_15_1]=branch(pthq_14_1,qmtot(15),tamb,linevec_15_1,contvec);
[p,h,rho,v,ve_15_2,msg,pthq_15_2]=branch(pthq_15_1,   qm(15),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_15_3,msg,pthq_15_3]=branch(pthq_15_2,   qm(15),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_15_4,msg,pthq_15_4]=branch(pthq_15_3,   qm(15),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_15_5,msg,pthq_15_5]=branch(pthq_15_4,   qm(15),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_16_1,msg,pthq_16_1]=branch(pthq_15_1,qmtot(16),tamb,linevec_16_1,contvec);
[p,h,rho,v,ve_16_2,msg,pthq_16_2]=branch(pthq_16_1,   qm(16),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_16_3,msg,pthq_16_3]=branch(pthq_16_2,   qm(16),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_16_4,msg,pthq_16_4]=branch(pthq_16_3,   qm(16),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_16_5,msg,pthq_16_5]=branch(pthq_16_4,   qm(16),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_17_1,msg,pthq_17_1]=branch(pthq_16_1,qmtot(17),tamb,linevec_17_1,contvec);
[p,h,rho,v,ve_17_2,msg,pthq_17_2]=branch(pthq_17_1,   qm(17),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_17_3,msg,pthq_17_3]=branch(pthq_17_2,   qm(17),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_17_4,msg,pthq_17_4]=branch(pthq_17_3,   qm(17),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_17_5,msg,pthq_17_5]=branch(pthq_17_4,   qm(17),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_18_1,msg,pthq_18_1]=branch(pthq_17_1,qmtot(18),tamb,linevec_18_1,contvec);
[p,h,rho,v,ve_18_2,msg,pthq_18_2]=branch(pthq_18_1,   qm(18),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_18_3,msg,pthq_18_3]=branch(pthq_18_2,   qm(18),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_18_4,msg,pthq_18_4]=branch(pthq_18_3,   qm(18),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_18_5,msg,pthq_18_5]=branch(pthq_18_4,   qm(18),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_19_1,msg,pthq_19_1]=branch(pthq_18_1,qmtot(19),tamb,linevec_19_1,contvec);
[p,h,rho,v,ve_19_2,msg,pthq_19_2]=branch(pthq_19_1,   qm(19),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_19_3,msg,pthq_19_3]=branch(pthq_19_2,   qm(19),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_19_4,msg,pthq_19_4]=branch(pthq_19_3,   qm(19),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_19_5,msg,pthq_19_5]=branch(pthq_19_4,   qm(19),tamb,linevec_99_5,contvec);
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```
[p,h,rho,v,ve_20_1,msg,pthq_20_1]=branch(pthq_19_1,qmtot(20),tamb,linevec_20_1,contvec);
[p,h,rho,v,ve_20_2,msg,pthq_20_2]=branch(pthq_20_1,   qm(20),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_20_3,msg,pthq_20_3]=branch(pthq_20_2,   qm(20),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_20_4,msg,pthq_20_4]=branch(pthq_20_3,   qm(20),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_20_5,msg,pthq_20_5]=branch(pthq_20_4,   qm(20),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_21_1,msg,pthq_21_1]=branch(pthq_20_1,qmtot(21),tamb,linevec_21_1,contvec);
[p,h,rho,v,ve_21_2,msg,pthq_21_2]=branch(pthq_21_1,   qm(21),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_21_3,msg,pthq_21_3]=branch(pthq_21_2,   qm(21),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_21_4,msg,pthq_21_4]=branch(pthq_21_3,   qm(21),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_21_5,msg,pthq_21_5]=branch(pthq_21_4,   qm(21),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_22_1,msg,pthq_22_1]=branch(pthq_21_1,qmtot(22),tamb,linevec_22_1,contvec);
[p,h,rho,v,ve_22_2,msg,pthq_22_2]=branch(pthq_22_1,   qm(22),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_22_3,msg,pthq_22_3]=branch(pthq_22_2,   qm(22),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_22_4,msg,pthq_22_4]=branch(pthq_22_3,   qm(22),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_22_5,msg,pthq_22_5]=branch(pthq_22_4,   qm(22),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_23_1,msg,pthq_23_1]=branch(pthq_22_1,qmtot(23),tamb,linevec_23_1,contvec);
[p,h,rho,v,ve_23_2,msg,pthq_23_2]=branch(pthq_23_1,   qm(23),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_23_3,msg,pthq_23_3]=branch(pthq_23_2,   qm(23),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_23_4,msg,pthq_23_4]=branch(pthq_23_3,   qm(23),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_23_5,msg,pthq_23_5]=branch(pthq_23_4,   qm(23),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_24_1,msg,pthq_24_1]=branch(pthq_23_1,qmtot(24),tamb,linevec_24_1,contvec);
[p,h,rho,v,ve_24_2,msg,pthq_24_2]=branch(pthq_24_1,   qm(24),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_24_3,msg,pthq_24_3]=branch(pthq_24_2,   qm(24),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_24_4,msg,pthq_24_4]=branch(pthq_24_3,   qm(24),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_24_5,msg,pthq_24_5]=branch(pthq_24_4,   qm(24),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_25_1,msg,pthq_25_1]=branch(pthq_24_1,qmtot(25),tamb,linevec_25_1,contvec);
[p,h,rho,v,ve_25_2,msg,pthq_25_2]=branch(pthq_25_1,   qm(25),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_25_3,msg,pthq_25_3]=branch(pthq_25_2,   qm(25),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_25_4,msg,pthq_25_4]=branch(pthq_25_3,   qm(25),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_25_5,msg,pthq_25_5]=branch(pthq_25_4,   qm(25),tamb,linevec_99_5,contvec);
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```
[p,h,rho,v,ve_26_1,msg,pthq_26_1]=branch(pthq_25_1,qmtot(26),tamb,linevec_26_1,contvec);
[p,h,rho,v,ve_26_2,msg,pthq_26_2]=branch(pthq_26_1,   qm(26),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_26_3,msg,pthq_26_3]=branch(pthq_26_2,   qm(26),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_26_4,msg,pthq_26_4]=branch(pthq_26_3,   qm(26),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_26_5,msg,pthq_26_5]=branch(pthq_26_4,   qm(26),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_27_1,msg,pthq_27_1]=branch(pthq_26_1,qmtot(27),tamb,linevec_27_1,contvec);
[p,h,rho,v,ve_27_2,msg,pthq_27_2]=branch(pthq_27_1,   qm(27),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_27_3,msg,pthq_27_3]=branch(pthq_27_2,   qm(27),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_27_4,msg,pthq_27_4]=branch(pthq_27_3,   qm(27),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_27_5,msg,pthq_27_5]=branch(pthq_27_4,   qm(27),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_28_1,msg,pthq_28_1]=branch(pthq_27_1,qmtot(28),tamb,linevec_28_1,contvec);
[p,h,rho,v,ve_28_2,msg,pthq_28_2]=branch(pthq_28_1,   qm(28),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_28_3,msg,pthq_28_3]=branch(pthq_28_2,   qm(28),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_28_4,msg,pthq_28_4]=branch(pthq_28_3,   qm(28),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_28_5,msg,pthq_28_5]=branch(pthq_28_4,   qm(28),tamb,linevec_99_5,contvec);

%start returns
[p,h,rho,v,ve_28_6,msg,pthq_28_6]=branch(pthq_28_5,qmtot(28),tamb,linevec_28_6,contvec);

hu_27_6=(pthq_28_6(3)*qmtot(28)+pthq_27_5(3)*qm(27))/(qmtot(28)+qm(27));
pthqu_27_6=[pthq_28_6(1),hu_27_6/4180.+273.16,hu_27_6,0.0];
[p,h,rho,v,ve_27_6,msg,pthq_27_6]=branch(pthqu_27_6,qmtot(27),tamb,linevec_27_6,contvec);

hu_26_6=(pthq_27_6(3)*qmtot(27)+pthq_26_5(3)*qm(26))/(qmtot(27)+qm(26));
pthqu_26_6=[pthq_27_6(1),hu_26_6/4180.+273.16,hu_26_6,0.0];
[p,h,rho,v,ve_26_6,msg,pthq_26_6]=branch(pthqu_26_6,qmtot(26),tamb,linevec_26_6,contvec);

hu_25_6=(pthq_26_6(3)*qmtot(26)+pthq_25_5(3)*qm(25))/(qmtot(26)+qm(25));
pthqu_25_6=[pthq_26_6(1),hu_25_6/4180.+273.16,hu_25_6,0.0];
[p,h,rho,v,ve_25_6,msg,pthq_25_6]=branch(pthqu_25_6,qmtot(25),tamb,linevec_25_6,contvec);

hu_24_6=(pthq_25_6(3)*qmtot(25)+pthq_24_5(3)*qm(24))/(qmtot(25)+qm(24));
pthqu_24_6=[pthq_25_6(1),hu_24_6/4180.+273.16,hu_24_6,0.0];
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```
[p,h,rho,v,ve_24_6,msg,pthq_24_6]=branch(pthqu_24_6,qmtot(24),tamb,linevec_24_6,contvec);

hu_23_6=(pthq_24_6(3)*qmtot(24)+pthq_23_5(3)*qm(23))/(qmtot(24)+qm(23));
pthqu_23_6=[pthq_24_6(1),hu_23_6/4180.+273.16,hu_23_6,0.0];
[p,h,rho,v,ve_23_6,msg,pthq_23_6]=branch(pthqu_23_6,qmtot(23),tamb,linevec_23_6,contvec);

hu_22_6=(pthq_23_6(3)*qmtot(23)+pthq_22_5(3)*qm(22))/(qmtot(23)+qm(22));
pthqu_22_6=[pthq_23_6(1),hu_22_6/4180.+273.16,hu_22_6,0.0];
[p,h,rho,v,ve_22_6,msg,pthq_22_6]=branch(pthqu_22_6,qmtot(22),tamb,linevec_22_6,contvec);

hu_21_6=(pthq_22_6(3)*qmtot(22)+pthq_21_5(3)*qm(21))/(qmtot(22)+qm(21));
pthqu_21_6=[pthq_22_6(1),hu_21_6/4180.+273.16,hu_21_6,0.0];
[p,h,rho,v,ve_21_6,msg,pthq_21_6]=branch(pthqu_21_6,qmtot(21),tamb,linevec_21_6,contvec);

hu_20_6=(pthq_21_6(3)*qmtot(21)+pthq_20_5(3)*qm(20))/(qmtot(21)+qm(20));
pthqu_20_6=[pthq_21_6(1),hu_20_6/4180.+273.16,hu_20_6,0.0];
[p,h,rho,v,ve_20_6,msg,pthq_20_6]=branch(pthqu_20_6,qmtot(20),tamb,linevec_20_6,contvec);

hu_19_6=(pthq_20_6(3)*qmtot(20)+pthq_19_5(3)*qm(19))/(qmtot(20)+qm(19));
pthqu_19_6=[pthq_20_6(1),hu_19_6/4180.+273.16,hu_19_6,0.0];
[p,h,rho,v,ve_19_6,msg,pthq_19_6]=branch(pthqu_19_6,qmtot(19),tamb,linevec_19_6,contvec);

hu_18_6=(pthq_19_6(3)*qmtot(19)+pthq_18_5(3)*qm(18))/(qmtot(19)+qm(18));
pthqu_18_6=[pthq_19_6(1),hu_18_6/4180.+273.16,hu_18_6,0.0];
[p,h,rho,v,ve_18_6,msg,pthq_18_6]=branch(pthqu_18_6,qmtot(18),tamb,linevec_18_6,contvec);

hu_17_6=(pthq_18_6(3)*qmtot(18)+pthq_17_5(3)*qm(17))/(qmtot(18)+qm(17));
pthqu_17_6=[pthq_18_6(1),hu_17_6/4180.+273.16,hu_17_6,0.0];
[p,h,rho,v,ve_17_6,msg,pthq_17_6]=branch(pthqu_17_6,qmtot(17),tamb,linevec_17_6,contvec);

hu_16_6=(pthq_17_6(3)*qmtot(17)+pthq_16_5(3)*qm(16))/(qmtot(17)+qm(16));
pthqu_16_6=[pthq_17_6(1),hu_16_6/4180.+273.16,hu_16_6,0.0];
[p,h,rho,v,ve_16_6,msg,pthq_16_6]=branch(pthqu_16_6,qmtot(16),tamb,linevec_16_6,contvec);

hu_15_6=(pthq_16_6(3)*qmtot(16)+pthq_15_5(3)*qm(15))/(qmtot(16)+qm(15));
pthqu_15_6=[pthq_16_6(1),hu_15_6/4180.+273.16,hu_15_6,0.0];
```

```
[p,h,rho,v,ve_15_6,msg,pthq_15_6]=branch(pthqu_15_6,qmtot(15),tamb,linevec_15_6,contvec);

hu_14_6=(pthq_15_6(3)*qmtot(15)+pthq_14_5(3)*qm(14))/(qmtot(15)+qm(14));
pthqu_14_6=[pthq_15_6(1),hu_14_6/4180.+273.16,hu_14_6,0.0];
[p,h,rho,v,ve_14_6,msg,pthq_14_6]=branch(pthqu_14_6,qmtot(14),tamb,linevec_14_6,contvec);

hu_13_6=(pthq_14_6(3)*qmtot(14)+pthq_13_5(3)*qm(13))/(qmtot(14)+qm(13));
pthqu_13_6=[pthq_14_6(1),hu_13_6/4180.+273.16,hu_13_6,0.0];
[p,h,rho,v,ve_13_6,msg,pthq_13_6]=branch(pthqu_13_6,qmtot(13),tamb,linevec_13_6,contvec);

hu_12_6=(pthq_13_6(3)*qmtot(13)+pthq_12_5(3)*qm(12))/(qmtot(13)+qm(12));
pthqu_12_6=[pthq_13_6(1),hu_12_6/4180.+273.16,hu_12_6,0.0];
[p,h,rho,v,ve_12_6,msg,pthq_12_6]=branch(pthqu_12_6,qmtot(12),tamb,linevec_12_6,contvec);

hu_11_6=(pthq_12_6(3)*qmtot(12)+pthq_11_5(3)*qm(11))/(qmtot(12)+qm(11));
pthqu_11_6=[pthq_12_6(1),hu_11_6/4180.+273.16,hu_11_6,0.0];
[p,h,rho,v,ve_11_6,msg,pthq_11_6]=branch(pthqu_11_6,qmtot(11),tamb,linevec_11_6,contvec);

hu_10_6=(pthq_11_6(3)*qmtot(11)+pthq_10_5(3)*qm(10))/(qmtot(11)+qm(10));
pthqu_10_6=[pthq_11_6(1),hu_10_6/4180.+273.16,hu_10_6,0.0];
[p,h,rho,v,ve_10_6,msg,pthq_10_6]=branch(pthqu_10_6,qmtot(10),tamb,linevec_10_6,contvec);

hu_09_6=(pthq_10_6(3)*qmtot(10)+pthq_09_5(3)*qm(09))/(qmtot(10)+qm(09));
pthqu_09_6=[pthq_10_6(1),hu_09_6/4180.+273.16,hu_09_6,0.0];
[p,h,rho,v,ve_09_6,msg,pthq_09_6]=branch(pthqu_09_6,qmtot(09),tamb,linevec_09_6,contvec);

hu_08_6=(pthq_09_6(3)*qmtot(09)+pthq_08_5(3)*qm(08))/(qmtot(09)+qm(08));
pthqu_08_6=[pthq_09_6(1),hu_08_6/4180.+273.16,hu_08_6,0.0];
[p,h,rho,v,ve_08_6,msg,pthq_08_6]=branch(pthqu_08_6,qmtot(08),tamb,linevec_08_6,contvec);

hu_07_6=(pthq_08_6(3)*qmtot(08)+pthq_07_5(3)*qm(07))/(qmtot(08)+qm(07));
pthqu_07_6=[pthq_08_6(1),hu_07_6/4180.+273.16,hu_07_6,0.0];
[p,h,rho,v,ve_07_6,msg,pthq_07_6]=branch(pthqu_07_6,qmtot(07),tamb,linevec_07_6,contvec);

hu_06_6=(pthq_07_6(3)*qmtot(07)+pthq_06_5(3)*qm(06))/(qmtot(07)+qm(06));
pthqu_06_6=[pthq_07_6(1),hu_06_6/4180.+273.16,hu_06_6,0.0];
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```
[p,h,rho,v,ve_06_6,msg,pthq_06_6]=branch(pthqu_06_6,qmtot(06),tamb,linevec_06_6,contvec);

hu_05_6=(pthq_06_6(3)*qmtot(06)+pthq_05_5(3)*qm(05))/(qmtot(06)+qm(05));
pthqu_05_6=[pthq_06_6(1),hu_05_6/4180.+273.16,hu_05_6,0.0];
[p,h,rho,v,ve_05_6,msg,pthq_05_6]=branch(pthqu_05_6,qmtot(05),tamb,linevec_05_6,contvec);

hu_04_6=(pthq_05_6(3)*qmtot(05)+pthq_04_5(3)*qm(04))/(qmtot(05)+qm(04));
pthqu_04_6=[pthq_05_6(1),hu_04_6/4180.+273.16,hu_04_6,0.0];
[p,h,rho,v,ve_04_6,msg,pthq_04_6]=branch(pthqu_04_6,qmtot(04),tamb,linevec_04_6,contvec);

hu_03_6=(pthq_04_6(3)*qmtot(04)+pthq_03_5(3)*qm(03))/(qmtot(04)+qm(03));
pthqu_03_6=[pthq_04_6(1),hu_03_6/4180.+273.16,hu_03_6,0.0];
[p,h,rho,v,ve_03_6,msg,pthq_03_6]=branch(pthqu_03_6,qmtot(03),tamb,linevec_03_6,contvec);

hu_02_6=(pthq_03_6(3)*qmtot(03)+pthq_02_5(3)*qm(2))/(qmtot(03)+qm(2));
pthqu_02_6=[pthq_03_6(1),hu_02_6/4180.+273.16,hu_02_6,0.0];
[p,h,rho,v,ve_02_6,msg,pthq_02_6]=branch(pthqu_02_6,qmtot(2),tamb,linevec_02_6,contvec);

hu_01_6=(pthq_02_6(3)*qmtot(02)+pthq_01_5(3)*qm(1))/(qmtot(02)+qm(1));
pthqu_01_6=[pthq_02_6(1),hu_01_6/4180.+273.16,hu_01_6,0.0];
[p,h,rho,v,ve_01_6,msg,pthq_01_6]=branch(pthqu_01_6,qmtot(1),tamb,linevec_01_6,contvec);

[p,h,rho,v,ve_00_2,msg,pthq_00_2]=branch(pthq_01_6,qmtot(1),tamb,linevec_00_2,contvec);
```

solversystem.m

```
%for SOLVER circuit

%Generic initialization
clear all;
relerr = 1e-4;      %relative error in iterations
itmx = 20;          %maximum number of iterations in any loop
dgns = 1.0;         %display message: 1.0, do not display: 0.0
contvec=[relerr,itmx,dgns];
kline  = 400.;      %W/(m*K), copper, Incropera fig 2.5, line wall thermal conductivity
kinsul = 0.038;     %0.038 W/(m*K), fiberglass coated duct liner, Incropera Table A.3
tamb = 297.0489;    %degK, ambient temperature = 75deg F

%thermostatic mixing valve conditions
p_tmv = 15e5;       %downstream pressure - not relevant
t_tmv = 322.049;    %downstream temperature = 120degF
h_tmv = 204356.;    %based on t_tmv
pthq_00_0=[p_tmv,t_tmv,h_tmv,0.0];  %provides upstream input for line after TMV

load qmfile99.mat;

%%%%%%%%%%% FLOORS %%%%%%%%%%%%%%%
%             length  id     od    th-ins  n  W/(mK) W/(mK)
linevec_99_2=[ 30., 1.505, 1.625, 1.500, 30, kline, kinsul];  %nom 1 1/2"
linevec_99_3=[ 15., 1.265, 1.375, 1.000, 15, kline, kinsul];  %nom 1 1/4"
linevec_99_4=[  9., 1.025, 1.125, 1.000,  9, kline, kinsul];  %nom 1"
linevec_99_5=[  6., 0.545, 0.625, 1.000,  6, kline, kinsul];  %nom 1/2"

%%%%%%%% RISERS %%%%%%%%%%%%%%%%%%%
%             length  id     od    th-ins  n  W/(mK) W/(mK)
linevec_00_1=[ 20., 2.465, 2.625, 1.500, 20, kline, kinsul];  %nom 2 1/2"
linevec_01_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_02_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_03_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_04_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
```

```
linevec_05_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_06_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_07_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_08_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_09_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_10_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_11_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_12_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_13_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_14_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_15_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_16_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_17_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_18_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_19_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_20_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_21_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_22_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_23_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_24_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_25_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_26_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_27_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_28_1=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"

%%%%%%%%%%%%%% RETURNS %%%%%%%%%%%%%%%%%%%%
%             length  id     od    th-ins  n  W/(mK) W/(mK)
linevec_00_2=[ 40., 1.985, 2.125, 1.500, 40, kline, kinsul];  %nom 2"
linevec_01_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_02_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_03_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_04_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_05_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_06_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_07_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_08_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_09_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
```

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linevec_10_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_11_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_12_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_13_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_14_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_15_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_16_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_17_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_18_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_19_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_20_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_21_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_22_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_23_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_24_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_25_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_26_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"
linevec_27_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"
linevec_28_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"

qmtot(28) = qm(28);
for i=27:-1:1
    qmtot(i)=qmtot(i+1)+qm(i);
end

[p,h,rho,v,ve_00_1,msg,pthq_00_1]=branch(pthq_00_0,qmtot(1),tamb,linevec_00_1,contvec);

[p,h,rho,v,ve_01_1,msg,pthq_01_1]=branch(pthq_00_1,qmtot(1),tamb,linevec_01_1,contvec);
[p,h,rho,v,ve_01_2,msg,pthq_01_2]=branch(pthq_01_1,   qm(1),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_01_3,msg,pthq_01_3]=branch(pthq_01_2,   qm(1),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_01_4,msg,pthq_01_4]=branch(pthq_01_3,   qm(1),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_01_5,msg,pthq_01_5]=branch(pthq_01_4,   qm(1),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_02_1,msg,pthq_02_1]=branch(pthq_01_1,qmtot(2),tamb,linevec_02_1,contvec);
[p,h,rho,v,ve_02_2,msg,pthq_02_2]=branch(pthq_02_1,   qm(2),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_02_3,msg,pthq_02_3]=branch(pthq_02_2,   qm(2),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_02_4,msg,pthq_02_4]=branch(pthq_02_3,   qm(2),tamb,linevec_99_4,contvec);
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[p,h,rho,v,ve_02_5,msg,pthq_02_5]=branch(pthq_02_4,   qm(2),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_03_1,msg,pthq_03_1]=branch(pthq_02_1,qmtot(3),tamb,linevec_03_1,contvec);
[p,h,rho,v,ve_03_2,msg,pthq_03_2]=branch(pthq_03_1,   qm(3),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_03_3,msg,pthq_03_3]=branch(pthq_03_2,   qm(3),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_03_4,msg,pthq_03_4]=branch(pthq_03_3,   qm(3),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_03_5,msg,pthq_03_5]=branch(pthq_03_4,   qm(3),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_04_1,msg,pthq_04_1]=branch(pthq_03_1,qmtot(4),tamb,linevec_04_1,contvec);
[p,h,rho,v,ve_04_2,msg,pthq_04_2]=branch(pthq_04_1,   qm(4),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_04_3,msg,pthq_04_3]=branch(pthq_04_2,   qm(4),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_04_4,msg,pthq_04_4]=branch(pthq_04_3,   qm(4),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_04_5,msg,pthq_04_5]=branch(pthq_04_4,   qm(4),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_05_1,msg,pthq_05_1]=branch(pthq_04_1,qmtot(5),tamb,linevec_05_1,contvec);
[p,h,rho,v,ve_05_2,msg,pthq_05_2]=branch(pthq_05_1,   qm(5),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_05_3,msg,pthq_05_3]=branch(pthq_05_2,   qm(5),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_05_4,msg,pthq_05_4]=branch(pthq_05_3,   qm(5),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_05_5,msg,pthq_05_5]=branch(pthq_05_4,   qm(5),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_06_1,msg,pthq_06_1]=branch(pthq_05_1,qmtot(6),tamb,linevec_06_1,contvec);
[p,h,rho,v,ve_06_2,msg,pthq_06_2]=branch(pthq_06_1,   qm(6),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_06_3,msg,pthq_06_3]=branch(pthq_06_2,   qm(6),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_06_4,msg,pthq_06_4]=branch(pthq_06_3,   qm(6),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_06_5,msg,pthq_06_5]=branch(pthq_06_4,   qm(6),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_07_1,msg,pthq_07_1]=branch(pthq_06_1,qmtot(7),tamb,linevec_07_1,contvec);
[p,h,rho,v,ve_07_2,msg,pthq_07_2]=branch(pthq_07_1,   qm(7),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_07_3,msg,pthq_07_3]=branch(pthq_07_2,   qm(7),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_07_4,msg,pthq_07_4]=branch(pthq_07_3,   qm(7),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_07_5,msg,pthq_07_5]=branch(pthq_07_4,   qm(7),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_08_1,msg,pthq_08_1]=branch(pthq_07_1,qmtot(8),tamb,linevec_08_1,contvec);
[p,h,rho,v,ve_08_2,msg,pthq_08_2]=branch(pthq_08_1,   qm(8),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_08_3,msg,pthq_08_3]=branch(pthq_08_2,   qm(8),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_08_4,msg,pthq_08_4]=branch(pthq_08_3,   qm(8),tamb,linevec_99_4,contvec);
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[p,h,rho,v,ve_08_5,msg,pthq_08_5]=branch(pthq_08_4,   qm(8),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_09_1,msg,pthq_09_1]=branch(pthq_08_1,qmtot(9),tamb,linevec_09_1,contvec);
[p,h,rho,v,ve_09_2,msg,pthq_09_2]=branch(pthq_09_1,   qm(9),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_09_3,msg,pthq_09_3]=branch(pthq_09_2,   qm(9),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_09_4,msg,pthq_09_4]=branch(pthq_09_3,   qm(9),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_09_5,msg,pthq_09_5]=branch(pthq_09_4,   qm(9),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_10_1,msg,pthq_10_1]=branch(pthq_09_1,qmtot(10),tamb,linevec_10_1,contvec);
[p,h,rho,v,ve_10_2,msg,pthq_10_2]=branch(pthq_10_1,   qm(10),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_10_3,msg,pthq_10_3]=branch(pthq_10_2,   qm(10),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_10_4,msg,pthq_10_4]=branch(pthq_10_3,   qm(10),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_10_5,msg,pthq_10_5]=branch(pthq_10_4,   qm(10),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_11_1,msg,pthq_11_1]=branch(pthq_10_1,qmtot(11),tamb,linevec_11_1,contvec);
[p,h,rho,v,ve_11_2,msg,pthq_11_2]=branch(pthq_11_1,   qm(11),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_11_3,msg,pthq_11_3]=branch(pthq_11_2,   qm(11),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_11_4,msg,pthq_11_4]=branch(pthq_11_3,   qm(11),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_11_5,msg,pthq_11_5]=branch(pthq_11_4,   qm(11),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_12_1,msg,pthq_12_1]=branch(pthq_11_1,qmtot(12),tamb,linevec_12_1,contvec);
[p,h,rho,v,ve_12_2,msg,pthq_12_2]=branch(pthq_12_1,   qm(12),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_12_3,msg,pthq_12_3]=branch(pthq_12_2,   qm(12),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_12_4,msg,pthq_12_4]=branch(pthq_12_3,   qm(12),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_12_5,msg,pthq_12_5]=branch(pthq_12_4,   qm(12),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_13_1,msg,pthq_13_1]=branch(pthq_12_1,qmtot(13),tamb,linevec_13_1,contvec);
[p,h,rho,v,ve_13_2,msg,pthq_13_2]=branch(pthq_13_1,   qm(13),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_13_3,msg,pthq_13_3]=branch(pthq_13_2,   qm(13),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_13_4,msg,pthq_13_4]=branch(pthq_13_3,   qm(13),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_13_5,msg,pthq_13_5]=branch(pthq_13_4,   qm(13),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_14_1,msg,pthq_14_1]=branch(pthq_13_1,qmtot(14),tamb,linevec_14_1,contvec);
[p,h,rho,v,ve_14_2,msg,pthq_14_2]=branch(pthq_14_1,   qm(14),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_14_3,msg,pthq_14_3]=branch(pthq_14_2,   qm(14),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_14_4,msg,pthq_14_4]=branch(pthq_14_3,   qm(14),tamb,linevec_99_4,contvec);
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[p,h,rho,v,ve_14_5,msg,pthq_14_5]=branch(pthq_14_4,   qm(14),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_15_1,msg,pthq_15_1]=branch(pthq_14_1,qmtot(15),tamb,linevec_15_1,contvec);
[p,h,rho,v,ve_15_2,msg,pthq_15_2]=branch(pthq_15_1,   qm(15),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_15_3,msg,pthq_15_3]=branch(pthq_15_2,   qm(15),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_15_4,msg,pthq_15_4]=branch(pthq_15_3,   qm(15),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_15_5,msg,pthq_15_5]=branch(pthq_15_4,   qm(15),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_16_1,msg,pthq_16_1]=branch(pthq_15_1,qmtot(16),tamb,linevec_16_1,contvec);
[p,h,rho,v,ve_16_2,msg,pthq_16_2]=branch(pthq_16_1,   qm(16),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_16_3,msg,pthq_16_3]=branch(pthq_16_2,   qm(16),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_16_4,msg,pthq_16_4]=branch(pthq_16_3,   qm(16),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_16_5,msg,pthq_16_5]=branch(pthq_16_4,   qm(16),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_17_1,msg,pthq_17_1]=branch(pthq_16_1,qmtot(17),tamb,linevec_17_1,contvec);
[p,h,rho,v,ve_17_2,msg,pthq_17_2]=branch(pthq_17_1,   qm(17),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_17_3,msg,pthq_17_3]=branch(pthq_17_2,   qm(17),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_17_4,msg,pthq_17_4]=branch(pthq_17_3,   qm(17),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_17_5,msg,pthq_17_5]=branch(pthq_17_4,   qm(17),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_18_1,msg,pthq_18_1]=branch(pthq_17_1,qmtot(18),tamb,linevec_18_1,contvec);
[p,h,rho,v,ve_18_2,msg,pthq_18_2]=branch(pthq_18_1,   qm(18),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_18_3,msg,pthq_18_3]=branch(pthq_18_2,   qm(18),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_18_4,msg,pthq_18_4]=branch(pthq_18_3,   qm(18),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_18_5,msg,pthq_18_5]=branch(pthq_18_4,   qm(18),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_19_1,msg,pthq_19_1]=branch(pthq_18_1,qmtot(19),tamb,linevec_19_1,contvec);
[p,h,rho,v,ve_19_2,msg,pthq_19_2]=branch(pthq_19_1,   qm(19),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_19_3,msg,pthq_19_3]=branch(pthq_19_2,   qm(19),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_19_4,msg,pthq_19_4]=branch(pthq_19_3,   qm(19),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_19_5,msg,pthq_19_5]=branch(pthq_19_4,   qm(19),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_20_1,msg,pthq_20_1]=branch(pthq_19_1,qmtot(20),tamb,linevec_20_1,contvec);
[p,h,rho,v,ve_20_2,msg,pthq_20_2]=branch(pthq_20_1,   qm(20),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_20_3,msg,pthq_20_3]=branch(pthq_20_2,   qm(20),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_20_4,msg,pthq_20_4]=branch(pthq_20_3,   qm(20),tamb,linevec_99_4,contvec);
```

```
[p,h,rho,v,ve_20_5,msg,pthq_20_5]=branch(pthq_20_4,   qm(20),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_21_1,msg,pthq_21_1]=branch(pthq_20_1,qmtot(21),tamb,linevec_21_1,contvec);
[p,h,rho,v,ve_21_2,msg,pthq_21_2]=branch(pthq_21_1,   qm(21),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_21_3,msg,pthq_21_3]=branch(pthq_21_2,   qm(21),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_21_4,msg,pthq_21_4]=branch(pthq_21_3,   qm(21),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_21_5,msg,pthq_21_5]=branch(pthq_21_4,   qm(21),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_22_1,msg,pthq_22_1]=branch(pthq_21_1,qmtot(22),tamb,linevec_22_1,contvec);
[p,h,rho,v,ve_22_2,msg,pthq_22_2]=branch(pthq_22_1,   qm(22),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_22_3,msg,pthq_22_3]=branch(pthq_22_2,   qm(22),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_22_4,msg,pthq_22_4]=branch(pthq_22_3,   qm(22),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_22_5,msg,pthq_22_5]=branch(pthq_22_4,   qm(22),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_23_1,msg,pthq_23_1]=branch(pthq_22_1,qmtot(23),tamb,linevec_23_1,contvec);
[p,h,rho,v,ve_23_2,msg,pthq_23_2]=branch(pthq_23_1,   qm(23),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_23_3,msg,pthq_23_3]=branch(pthq_23_2,   qm(23),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_23_4,msg,pthq_23_4]=branch(pthq_23_3,   qm(23),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_23_5,msg,pthq_23_5]=branch(pthq_23_4,   qm(23),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_24_1,msg,pthq_24_1]=branch(pthq_23_1,qmtot(24),tamb,linevec_24_1,contvec);
[p,h,rho,v,ve_24_2,msg,pthq_24_2]=branch(pthq_24_1,   qm(24),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_24_3,msg,pthq_24_3]=branch(pthq_24_2,   qm(24),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_24_4,msg,pthq_24_4]=branch(pthq_24_3,   qm(24),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_24_5,msg,pthq_24_5]=branch(pthq_24_4,   qm(24),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_25_1,msg,pthq_25_1]=branch(pthq_24_1,qmtot(25),tamb,linevec_25_1,contvec);
[p,h,rho,v,ve_25_2,msg,pthq_25_2]=branch(pthq_25_1,   qm(25),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_25_3,msg,pthq_25_3]=branch(pthq_25_2,   qm(25),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_25_4,msg,pthq_25_4]=branch(pthq_25_3,   qm(25),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_25_5,msg,pthq_25_5]=branch(pthq_25_4,   qm(25),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_26_1,msg,pthq_26_1]=branch(pthq_25_1,qmtot(26),tamb,linevec_26_1,contvec);
[p,h,rho,v,ve_26_2,msg,pthq_26_2]=branch(pthq_26_1,   qm(26),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_26_3,msg,pthq_26_3]=branch(pthq_26_2,   qm(26),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_26_4,msg,pthq_26_4]=branch(pthq_26_3,   qm(26),tamb,linevec_99_4,contvec);
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```
[p,h,rho,v,ve_26_5,msg,pthq_26_5]=branch(pthq_26_4,   qm(26),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_27_1,msg,pthq_27_1]=branch(pthq_26_1,qmtot(27),tamb,linevec_27_1,contvec);
[p,h,rho,v,ve_27_2,msg,pthq_27_2]=branch(pthq_27_1,   qm(27),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_27_3,msg,pthq_27_3]=branch(pthq_27_2,   qm(27),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_27_4,msg,pthq_27_4]=branch(pthq_27_3,   qm(27),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_27_5,msg,pthq_27_5]=branch(pthq_27_4,   qm(27),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_28_1,msg,pthq_28_1]=branch(pthq_27_1,qmtot(28),tamb,linevec_28_1,contvec);
[p,h,rho,v,ve_28_2,msg,pthq_28_2]=branch(pthq_28_1,   qm(28),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_28_3,msg,pthq_28_3]=branch(pthq_28_2,   qm(28),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_28_4,msg,pthq_28_4]=branch(pthq_28_3,   qm(28),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_28_5,msg,pthq_28_5]=branch(pthq_28_4,   qm(28),tamb,linevec_99_5,contvec);

%start returns
[p,h,rho,v,ve_28_6,msg,pthq_28_6]=branch(pthq_28_5,qmtot(28),tamb,linevec_28_6,contvec);

hu_27_6=(pthq_28_6(3)*qmtot(28)+pthq_27_5(3)*qm(27))/(qmtot(28)+qm(27));
pthqu_27_6=[pthq_28_6(1),hu_27_6/4180.+273.16,hu_27_6,0.0];
[p,h,rho,v,ve_27_6,msg,pthq_27_6]=branch(pthqu_27_6,qmtot(27),tamb,linevec_27_6,contvec);

hu_26_6=(pthq_27_6(3)*qmtot(27)+pthq_26_5(3)*qm(26))/(qmtot(27)+qm(26));
pthqu_26_6=[pthq_27_6(1),hu_26_6/4180.+273.16,hu_26_6,0.0];
[p,h,rho,v,ve_26_6,msg,pthq_26_6]=branch(pthqu_26_6,qmtot(26),tamb,linevec_26_6,contvec);

hu_25_6=(pthq_26_6(3)*qmtot(26)+pthq_25_5(3)*qm(25))/(qmtot(26)+qm(25));
pthqu_25_6=[pthq_26_6(1),hu_25_6/4180.+273.16,hu_25_6,0.0];
[p,h,rho,v,ve_25_6,msg,pthq_25_6]=branch(pthqu_25_6,qmtot(25),tamb,linevec_25_6,contvec);

hu_24_6=(pthq_25_6(3)*qmtot(25)+pthq_24_5(3)*qm(24))/(qmtot(25)+qm(24));
pthqu_24_6=[pthq_25_6(1),hu_24_6/4180.+273.16,hu_24_6,0.0];
[p,h,rho,v,ve_24_6,msg,pthq_24_6]=branch(pthqu_24_6,qmtot(24),tamb,linevec_24_6,contvec);

hu_23_6=(pthq_24_6(3)*qmtot(24)+pthq_23_5(3)*qm(23))/(qmtot(24)+qm(23));
pthqu_23_6=[pthq_24_6(1),hu_23_6/4180.+273.16,hu_23_6,0.0];
[p,h,rho,v,ve_23_6,msg,pthq_23_6]=branch(pthqu_23_6,qmtot(23),tamb,linevec_23_6,contvec);
```

```
hu_22_6=(pthq_23_6(3)*qmtot(23)+pthq_22_5(3)*qm(22))/(qmtot(23)+qm(22));
pthqu_22_6=[pthq_23_6(1),hu_22_6/4180.+273.16,hu_22_6,0.0];
[p,h,rho,v,ve_22_6,msg,pthq_22_6]=branch(pthqu_22_6,qmtot(22),tamb,linevec_22_6,contvec);

hu_21_6=(pthq_22_6(3)*qmtot(22)+pthq_21_5(3)*qm(21))/(qmtot(22)+qm(21));
pthqu_21_6=[pthq_22_6(1),hu_21_6/4180.+273.16,hu_21_6,0.0];
[p,h,rho,v,ve_21_6,msg,pthq_21_6]=branch(pthqu_21_6,qmtot(21),tamb,linevec_21_6,contvec);

hu_20_6=(pthq_21_6(3)*qmtot(21)+pthq_20_5(3)*qm(20))/(qmtot(21)+qm(20));
pthqu_20_6=[pthq_21_6(1),hu_20_6/4180.+273.16,hu_20_6,0.0];
[p,h,rho,v,ve_20_6,msg,pthq_20_6]=branch(pthqu_20_6,qmtot(20),tamb,linevec_20_6,contvec);

hu_19_6=(pthq_20_6(3)*qmtot(20)+pthq_19_5(3)*qm(19))/(qmtot(20)+qm(19));
pthqu_19_6=[pthq_20_6(1),hu_19_6/4180.+273.16,hu_19_6,0.0];
[p,h,rho,v,ve_19_6,msg,pthq_19_6]=branch(pthqu_19_6,qmtot(19),tamb,linevec_19_6,contvec);

hu_18_6=(pthq_19_6(3)*qmtot(19)+pthq_18_5(3)*qm(18))/(qmtot(19)+qm(18));
pthqu_18_6=[pthq_19_6(1),hu_18_6/4180.+273.16,hu_18_6,0.0];
[p,h,rho,v,ve_18_6,msg,pthq_18_6]=branch(pthqu_18_6,qmtot(18),tamb,linevec_18_6,contvec);

hu_17_6=(pthq_18_6(3)*qmtot(18)+pthq_17_5(3)*qm(17))/(qmtot(18)+qm(17));
pthqu_17_6=[pthq_18_6(1),hu_17_6/4180.+273.16,hu_17_6,0.0];
[p,h,rho,v,ve_17_6,msg,pthq_17_6]=branch(pthqu_17_6,qmtot(17),tamb,linevec_17_6,contvec);

hu_16_6=(pthq_17_6(3)*qmtot(17)+pthq_16_5(3)*qm(16))/(qmtot(17)+qm(16));
pthqu_16_6=[pthq_17_6(1),hu_16_6/4180.+273.16,hu_16_6,0.0];
[p,h,rho,v,ve_16_6,msg,pthq_16_6]=branch(pthqu_16_6,qmtot(16),tamb,linevec_16_6,contvec);

hu_15_6=(pthq_16_6(3)*qmtot(16)+pthq_15_5(3)*qm(15))/(qmtot(16)+qm(15));
pthqu_15_6=[pthq_16_6(1),hu_15_6/4180.+273.16,hu_15_6,0.0];
[p,h,rho,v,ve_15_6,msg,pthq_15_6]=branch(pthqu_15_6,qmtot(15),tamb,linevec_15_6,contvec);

hu_14_6=(pthq_15_6(3)*qmtot(15)+pthq_14_5(3)*qm(14))/(qmtot(15)+qm(14));
pthqu_14_6=[pthq_15_6(1),hu_14_6/4180.+273.16,hu_14_6,0.0];
[p,h,rho,v,ve_14_6,msg,pthq_14_6]=branch(pthqu_14_6,qmtot(14),tamb,linevec_14_6,contvec);
```

```
hu_13_6=(pthq_14_6(3)*qmtot(14)+pthq_13_5(3)*qm(13))/(qmtot(14)+qm(13));
pthqu_13_6=[pthq_14_6(1),hu_13_6/4180.+273.16,hu_13_6,0.0];
[p,h,rho,v,ve_13_6,msg,pthq_13_6]=branch(pthqu_13_6,qmtot(13),tamb,linevec_13_6,contvec);

hu_12_6=(pthq_13_6(3)*qmtot(13)+pthq_12_5(3)*qm(12))/(qmtot(13)+qm(12));
pthqu_12_6=[pthq_13_6(1),hu_12_6/4180.+273.16,hu_12_6,0.0];
[p,h,rho,v,ve_12_6,msg,pthq_12_6]=branch(pthqu_12_6,qmtot(12),tamb,linevec_12_6,contvec);

hu_11_6=(pthq_12_6(3)*qmtot(12)+pthq_11_5(3)*qm(11))/(qmtot(12)+qm(11));
pthqu_11_6=[pthq_12_6(1),hu_11_6/4180.+273.16,hu_11_6,0.0];
[p,h,rho,v,ve_11_6,msg,pthq_11_6]=branch(pthqu_11_6,qmtot(11),tamb,linevec_11_6,contvec);

hu_10_6=(pthq_11_6(3)*qmtot(11)+pthq_10_5(3)*qm(10))/(qmtot(11)+qm(10));
pthqu_10_6=[pthq_11_6(1),hu_10_6/4180.+273.16,hu_10_6,0.0];
[p,h,rho,v,ve_10_6,msg,pthq_10_6]=branch(pthqu_10_6,qmtot(10),tamb,linevec_10_6,contvec);

hu_09_6=(pthq_10_6(3)*qmtot(10)+pthq_09_5(3)*qm(09))/(qmtot(10)+qm(09));
pthqu_09_6=[pthq_10_6(1),hu_09_6/4180.+273.16,hu_09_6,0.0];
[p,h,rho,v,ve_09_6,msg,pthq_09_6]=branch(pthqu_09_6,qmtot(09),tamb,linevec_09_6,contvec);

hu_08_6=(pthq_09_6(3)*qmtot(09)+pthq_08_5(3)*qm(08))/(qmtot(09)+qm(08));
pthqu_08_6=[pthq_09_6(1),hu_08_6/4180.+273.16,hu_08_6,0.0];
[p,h,rho,v,ve_08_6,msg,pthq_08_6]=branch(pthqu_08_6,qmtot(08),tamb,linevec_08_6,contvec);

hu_07_6=(pthq_08_6(3)*qmtot(08)+pthq_07_5(3)*qm(07))/(qmtot(08)+qm(07));
pthqu_07_6=[pthq_08_6(1),hu_07_6/4180.+273.16,hu_07_6,0.0];
[p,h,rho,v,ve_07_6,msg,pthq_07_6]=branch(pthqu_07_6,qmtot(07),tamb,linevec_07_6,contvec);

hu_06_6=(pthq_07_6(3)*qmtot(07)+pthq_06_5(3)*qm(06))/(qmtot(07)+qm(06));
pthqu_06_6=[pthq_07_6(1),hu_06_6/4180.+273.16,hu_06_6,0.0];
[p,h,rho,v,ve_06_6,msg,pthq_06_6]=branch(pthqu_06_6,qmtot(06),tamb,linevec_06_6,contvec);

hu_05_6=(pthq_06_6(3)*qmtot(06)+pthq_05_5(3)*qm(05))/(qmtot(06)+qm(05));
pthqu_05_6=[pthq_06_6(1),hu_05_6/4180.+273.16,hu_05_6,0.0];
[p,h,rho,v,ve_05_6,msg,pthq_05_6]=branch(pthqu_05_6,qmtot(05),tamb,linevec_05_6,contvec);
```

```
hu_04_6=(pthq_05_6(3)*qmtot(05)+pthq_04_5(3)*qm(04))/(qmtot(05)+qm(04));
pthqu_04_6=[pthq_05_6(1),hu_04_6/4180.+273.16,hu_04_6,0.0];
[p,h,rho,v,ve_04_6,msg,pthq_04_6]=branch(pthqu_04_6,qmtot(04),tamb,linevec_04_6,contvec);

hu_03_6=(pthq_04_6(3)*qmtot(04)+pthq_03_5(3)*qm(03))/(qmtot(04)+qm(03));
pthqu_03_6=[pthq_04_6(1),hu_03_6/4180.+273.16,hu_03_6,0.0];
[p,h,rho,v,ve_03_6,msg,pthq_03_6]=branch(pthqu_03_6,qmtot(03),tamb,linevec_03_6,contvec);

hu_02_6=(pthq_03_6(3)*qmtot(03)+pthq_02_5(3)*qm(2))/(qmtot(03)+qm(2));
pthqu_02_6=[pthq_03_6(1),hu_02_6/4180.+273.16,hu_02_6,0.0];
[p,h,rho,v,ve_02_6,msg,pthq_02_6]=branch(pthqu_02_6,qmtot(2),tamb,linevec_02_6,contvec);

hu_01_6=(pthq_02_6(3)*qmtot(02)+pthq_01_5(3)*qm(1))/(qmtot(02)+qm(1));
pthqu_01_6=[pthq_02_6(1),hu_01_6/4180.+273.16,hu_01_6,0.0];
[p,h,rho,v,ve_01_6,msg,pthq_01_6]=branch(pthqu_01_6,qmtot(1),tamb,linevec_01_6,contvec);

[p,h,rho,v,ve_00_2,msg,pthq_00_2]=branch(pthq_01_6,qmtot(1),tamb,linevec_00_2,contvec);
```

solversystem01.m

```
function tvlvu=solversystem01(qm)
%For SOLVER system, calculate the full system for give flow rate vector
%Lines are all for Type L domestic water copper tube

relerr = 1e-4;      %relative error in iterations
itmx = 20;          %maximum number of iterations in any loop
dgns = 1.0;         %display message: 1.0, do not display: 0.0
contvec=[relerr,itmx,dgns];
kline  = 400.;      %W/(m*K), copper, Incropera fig 2.5, line wall thermal conductivity
kinsul = 0.038;     %0.038 W/(m*K), fiberglass coated duct liner, Incropera Table A.3
tamb = 297.0489;    %degK, ambient temperature = 75deg F

%thermostatic mixing valve conditions
p_tmv = 15e5;       %downstream pressure - not relevant
t_tmv = 322.049;    %downstream temperature = 120degF
h_tmv = 204356.;    %based on t_tmv
pthq_00_0=[p_tmv,t_tmv,h_tmv,0.0];  %provides upstream input for line after TMV

%%%%%%%%%%% FLOORS %%%%%%%%%%%%%%%
%             length  id     od   th-ins  n  W/(mK) W/(mK)
linevec_99_2=[ 30., 1.505, 1.625, 1.500, 30, kline, kinsul];  %nom 1 1/2"
linevec_99_3=[ 15., 1.265, 1.375, 1.000, 15, kline, kinsul];  %nom 1 1/4"
linevec_99_4=[  9., 1.025, 1.125, 1.000,  9, kline, kinsul];  %nom 1"
linevec_99_5=[  6., 0.545, 0.625, 1.000,  6, kline, kinsul];  %nom 1/2"

%%%%%%%% RISERS %%%%%%%%%%%%%%%%%%%
%             length  id     od   th-ins  n  W/(mK) W/(mK)
linevec_00_1=[ 20., 2.465, 2.625, 1.500, 20, kline, kinsul];  %nom 2 1/2"
linevec_01_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_02_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_03_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_04_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
linevec_05_1=[ 12., 2.465, 2.625, 1.500, 12, kline, kinsul];  %nom 2 1/2"
```

```
linevec_06_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_07_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_08_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_09_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_10_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_11_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_12_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_13_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_14_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_15_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_16_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_17_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_18_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_19_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_20_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_21_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_22_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_23_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_24_1=[ 12., 1.985, 2.125, 1.500, 12, kline, kinsul];  %nom 2"
linevec_25_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_26_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_27_1=[ 12., 1.505, 1.625, 1.500, 12, kline, kinsul];  %nom 1 1/2"
linevec_28_1=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"

%%%%%%%%%%%%%%% RETURNS %%%%%%%%%%%%%%%%%%%%%
%             length  id     od   th-ins  n  W/(mK) W/(mK)
linevec_00_2=[ 40., 1.985, 2.125, 1.500, 40, kline, kinsul];  %nom 2"
linevec_01_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_02_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_03_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_04_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_05_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_06_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_07_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_08_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_09_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_10_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
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linevec_11_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_12_6=[ 12., 1.265, 1.375, 1.000, 12, kline, kinsul];  %nom 1 1/4"
linevec_13_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_14_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_15_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_16_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_17_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_18_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_19_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_20_6=[ 12., 1.025, 1.125, 1.000, 12, kline, kinsul];  %nom 1"
linevec_21_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_22_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_23_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_24_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_25_6=[ 12., 0.785, 0.875, 1.000, 12, kline, kinsul];  %nom 3/4"
linevec_26_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"
linevec_27_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"
linevec_28_6=[ 12., 0.545, 0.625, 1.000, 12, kline, kinsul];  %nom 1/2"

qmtot(28) = qm(28);
for i=27:-1:1
    qmtot(i)=qmtot(i+1)+qm(i);
end

[p,h,rho,v,ve_00_1,msg,pthq_00_1]=branch(pthq_00_0,qmtot(1),tamb,linevec_00_1,contvec);

[p,h,rho,v,ve_01_1,msg,pthq_01_1]=branch(pthq_00_1,qmtot(1),tamb,linevec_01_1,contvec);
[p,h,rho,v,ve_01_2,msg,pthq_01_2]=branch(pthq_01_1,   qm(1),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_01_3,msg,pthq_01_3]=branch(pthq_01_2,   qm(1),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_01_4,msg,pthq_01_4]=branch(pthq_01_3,   qm(1),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_01_5,msg,pthq_01_5]=branch(pthq_01_4,   qm(1),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_02_1,msg,pthq_02_1]=branch(pthq_01_1,qmtot(2),tamb,linevec_02_1,contvec);
[p,h,rho,v,ve_02_2,msg,pthq_02_2]=branch(pthq_02_1,   qm(2),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_02_3,msg,pthq_02_3]=branch(pthq_02_2,   qm(2),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_02_4,msg,pthq_02_4]=branch(pthq_02_3,   qm(2),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_02_5,msg,pthq_02_5]=branch(pthq_02_4,   qm(2),tamb,linevec_99_5,contvec);
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[p,h,rho,v,ve_03_1,msg,pthq_03_1]=branch(pthq_02_1,qmtot(3),tamb,linevec_03_1,contvec);
[p,h,rho,v,ve_03_2,msg,pthq_03_2]=branch(pthq_03_1,   qm(3),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_03_3,msg,pthq_03_3]=branch(pthq_03_2,   qm(3),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_03_4,msg,pthq_03_4]=branch(pthq_03_3,   qm(3),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_03_5,msg,pthq_03_5]=branch(pthq_03_4,   qm(3),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_04_1,msg,pthq_04_1]=branch(pthq_03_1,qmtot(4),tamb,linevec_04_1,contvec);
[p,h,rho,v,ve_04_2,msg,pthq_04_2]=branch(pthq_04_1,   qm(4),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_04_3,msg,pthq_04_3]=branch(pthq_04_2,   qm(4),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_04_4,msg,pthq_04_4]=branch(pthq_04_3,   qm(4),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_04_5,msg,pthq_04_5]=branch(pthq_04_4,   qm(4),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_05_1,msg,pthq_05_1]=branch(pthq_04_1,qmtot(5),tamb,linevec_05_1,contvec);
[p,h,rho,v,ve_05_2,msg,pthq_05_2]=branch(pthq_05_1,   qm(5),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_05_3,msg,pthq_05_3]=branch(pthq_05_2,   qm(5),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_05_4,msg,pthq_05_4]=branch(pthq_05_3,   qm(5),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_05_5,msg,pthq_05_5]=branch(pthq_05_4,   qm(5),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_06_1,msg,pthq_06_1]=branch(pthq_05_1,qmtot(6),tamb,linevec_06_1,contvec);
[p,h,rho,v,ve_06_2,msg,pthq_06_2]=branch(pthq_06_1,   qm(6),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_06_3,msg,pthq_06_3]=branch(pthq_06_2,   qm(6),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_06_4,msg,pthq_06_4]=branch(pthq_06_3,   qm(6),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_06_5,msg,pthq_06_5]=branch(pthq_06_4,   qm(6),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_07_1,msg,pthq_07_1]=branch(pthq_06_1,qmtot(7),tamb,linevec_07_1,contvec);
[p,h,rho,v,ve_07_2,msg,pthq_07_2]=branch(pthq_07_1,   qm(7),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_07_3,msg,pthq_07_3]=branch(pthq_07_2,   qm(7),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_07_4,msg,pthq_07_4]=branch(pthq_07_3,   qm(7),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_07_5,msg,pthq_07_5]=branch(pthq_07_4,   qm(7),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_08_1,msg,pthq_08_1]=branch(pthq_07_1,qmtot(8),tamb,linevec_08_1,contvec);
[p,h,rho,v,ve_08_2,msg,pthq_08_2]=branch(pthq_08_1,   qm(8),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_08_3,msg,pthq_08_3]=branch(pthq_08_2,   qm(8),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_08_4,msg,pthq_08_4]=branch(pthq_08_3,   qm(8),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_08_5,msg,pthq_08_5]=branch(pthq_08_4,   qm(8),tamb,linevec_99_5,contvec);
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[p,h,rho,v,ve_09_1,msg,pthq_09_1]=branch(pthq_08_1,qmtot(9),tamb,linevec_09_1,contvec);
[p,h,rho,v,ve_09_2,msg,pthq_09_2]=branch(pthq_09_1,   qm(9),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_09_3,msg,pthq_09_3]=branch(pthq_09_2,   qm(9),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_09_4,msg,pthq_09_4]=branch(pthq_09_3,   qm(9),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_09_5,msg,pthq_09_5]=branch(pthq_09_4,   qm(9),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_10_1,msg,pthq_10_1]=branch(pthq_09_1,qmtot(10),tamb,linevec_10_1,contvec);
[p,h,rho,v,ve_10_2,msg,pthq_10_2]=branch(pthq_10_1,   qm(10),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_10_3,msg,pthq_10_3]=branch(pthq_10_2,   qm(10),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_10_4,msg,pthq_10_4]=branch(pthq_10_3,   qm(10),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_10_5,msg,pthq_10_5]=branch(pthq_10_4,   qm(10),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_11_1,msg,pthq_11_1]=branch(pthq_10_1,qmtot(11),tamb,linevec_11_1,contvec);
[p,h,rho,v,ve_11_2,msg,pthq_11_2]=branch(pthq_11_1,   qm(11),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_11_3,msg,pthq_11_3]=branch(pthq_11_2,   qm(11),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_11_4,msg,pthq_11_4]=branch(pthq_11_3,   qm(11),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_11_5,msg,pthq_11_5]=branch(pthq_11_4,   qm(11),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_12_1,msg,pthq_12_1]=branch(pthq_11_1,qmtot(12),tamb,linevec_12_1,contvec);
[p,h,rho,v,ve_12_2,msg,pthq_12_2]=branch(pthq_12_1,   qm(12),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_12_3,msg,pthq_12_3]=branch(pthq_12_2,   qm(12),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_12_4,msg,pthq_12_4]=branch(pthq_12_3,   qm(12),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_12_5,msg,pthq_12_5]=branch(pthq_12_4,   qm(12),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_13_1,msg,pthq_13_1]=branch(pthq_12_1,qmtot(13),tamb,linevec_13_1,contvec);
[p,h,rho,v,ve_13_2,msg,pthq_13_2]=branch(pthq_13_1,   qm(13),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_13_3,msg,pthq_13_3]=branch(pthq_13_2,   qm(13),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_13_4,msg,pthq_13_4]=branch(pthq_13_3,   qm(13),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_13_5,msg,pthq_13_5]=branch(pthq_13_4,   qm(13),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_14_1,msg,pthq_14_1]=branch(pthq_13_1,qmtot(14),tamb,linevec_14_1,contvec);
[p,h,rho,v,ve_14_2,msg,pthq_14_2]=branch(pthq_14_1,   qm(14),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_14_3,msg,pthq_14_3]=branch(pthq_14_2,   qm(14),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_14_4,msg,pthq_14_4]=branch(pthq_14_3,   qm(14),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_14_5,msg,pthq_14_5]=branch(pthq_14_4,   qm(14),tamb,linevec_99_5,contvec);
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[p,h,rho,v,ve_15_1,msg,pthq_15_1]=branch(pthq_14_1,qmtot(15),tamb,linevec_15_1,contvec);
[p,h,rho,v,ve_15_2,msg,pthq_15_2]=branch(pthq_15_1,   qm(15),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_15_3,msg,pthq_15_3]=branch(pthq_15_2,   qm(15),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_15_4,msg,pthq_15_4]=branch(pthq_15_3,   qm(15),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_15_5,msg,pthq_15_5]=branch(pthq_15_4,   qm(15),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_16_1,msg,pthq_16_1]=branch(pthq_15_1,qmtot(16),tamb,linevec_16_1,contvec);
[p,h,rho,v,ve_16_2,msg,pthq_16_2]=branch(pthq_16_1,   qm(16),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_16_3,msg,pthq_16_3]=branch(pthq_16_2,   qm(16),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_16_4,msg,pthq_16_4]=branch(pthq_16_3,   qm(16),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_16_5,msg,pthq_16_5]=branch(pthq_16_4,   qm(16),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_17_1,msg,pthq_17_1]=branch(pthq_16_1,qmtot(17),tamb,linevec_17_1,contvec);
[p,h,rho,v,ve_17_2,msg,pthq_17_2]=branch(pthq_17_1,   qm(17),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_17_3,msg,pthq_17_3]=branch(pthq_17_2,   qm(17),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_17_4,msg,pthq_17_4]=branch(pthq_17_3,   qm(17),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_17_5,msg,pthq_17_5]=branch(pthq_17_4,   qm(17),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_18_1,msg,pthq_18_1]=branch(pthq_17_1,qmtot(18),tamb,linevec_18_1,contvec);
[p,h,rho,v,ve_18_2,msg,pthq_18_2]=branch(pthq_18_1,   qm(18),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_18_3,msg,pthq_18_3]=branch(pthq_18_2,   qm(18),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_18_4,msg,pthq_18_4]=branch(pthq_18_3,   qm(18),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_18_5,msg,pthq_18_5]=branch(pthq_18_4,   qm(18),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_19_1,msg,pthq_19_1]=branch(pthq_18_1,qmtot(19),tamb,linevec_19_1,contvec);
[p,h,rho,v,ve_19_2,msg,pthq_19_2]=branch(pthq_19_1,   qm(19),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_19_3,msg,pthq_19_3]=branch(pthq_19_2,   qm(19),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_19_4,msg,pthq_19_4]=branch(pthq_19_3,   qm(19),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_19_5,msg,pthq_19_5]=branch(pthq_19_4,   qm(19),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_20_1,msg,pthq_20_1]=branch(pthq_19_1,qmtot(20),tamb,linevec_20_1,contvec);
[p,h,rho,v,ve_20_2,msg,pthq_20_2]=branch(pthq_20_1,   qm(20),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_20_3,msg,pthq_20_3]=branch(pthq_20_2,   qm(20),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_20_4,msg,pthq_20_4]=branch(pthq_20_3,   qm(20),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_20_5,msg,pthq_20_5]=branch(pthq_20_4,   qm(20),tamb,linevec_99_5,contvec);
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[p,h,rho,v,ve_21_1,msg,pthq_21_1]=branch(pthq_20_1,qmtot(21),tamb,linevec_21_1,contvec);
[p,h,rho,v,ve_21_2,msg,pthq_21_2]=branch(pthq_21_1,   qm(21),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_21_3,msg,pthq_21_3]=branch(pthq_21_2,   qm(21),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_21_4,msg,pthq_21_4]=branch(pthq_21_3,   qm(21),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_21_5,msg,pthq_21_5]=branch(pthq_21_4,   qm(21),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_22_1,msg,pthq_22_1]=branch(pthq_21_1,qmtot(22),tamb,linevec_22_1,contvec);
[p,h,rho,v,ve_22_2,msg,pthq_22_2]=branch(pthq_22_1,   qm(22),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_22_3,msg,pthq_22_3]=branch(pthq_22_2,   qm(22),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_22_4,msg,pthq_22_4]=branch(pthq_22_3,   qm(22),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_22_5,msg,pthq_22_5]=branch(pthq_22_4,   qm(22),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_23_1,msg,pthq_23_1]=branch(pthq_22_1,qmtot(23),tamb,linevec_23_1,contvec);
[p,h,rho,v,ve_23_2,msg,pthq_23_2]=branch(pthq_23_1,   qm(23),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_23_3,msg,pthq_23_3]=branch(pthq_23_2,   qm(23),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_23_4,msg,pthq_23_4]=branch(pthq_23_3,   qm(23),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_23_5,msg,pthq_23_5]=branch(pthq_23_4,   qm(23),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_24_1,msg,pthq_24_1]=branch(pthq_23_1,qmtot(24),tamb,linevec_24_1,contvec);
[p,h,rho,v,ve_24_2,msg,pthq_24_2]=branch(pthq_24_1,   qm(24),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_24_3,msg,pthq_24_3]=branch(pthq_24_2,   qm(24),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_24_4,msg,pthq_24_4]=branch(pthq_24_3,   qm(24),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_24_5,msg,pthq_24_5]=branch(pthq_24_4,   qm(24),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_25_1,msg,pthq_25_1]=branch(pthq_24_1,qmtot(25),tamb,linevec_25_1,contvec);
[p,h,rho,v,ve_25_2,msg,pthq_25_2]=branch(pthq_25_1,   qm(25),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_25_3,msg,pthq_25_3]=branch(pthq_25_2,   qm(25),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_25_4,msg,pthq_25_4]=branch(pthq_25_3,   qm(25),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_25_5,msg,pthq_25_5]=branch(pthq_25_4,   qm(25),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_26_1,msg,pthq_26_1]=branch(pthq_25_1,qmtot(26),tamb,linevec_26_1,contvec);
[p,h,rho,v,ve_26_2,msg,pthq_26_2]=branch(pthq_26_1,   qm(26),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_26_3,msg,pthq_26_3]=branch(pthq_26_2,   qm(26),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_26_4,msg,pthq_26_4]=branch(pthq_26_3,   qm(26),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_26_5,msg,pthq_26_5]=branch(pthq_26_4,   qm(26),tamb,linevec_99_5,contvec);
```

```
[p,h,rho,v,ve_27_1,msg,pthq_27_1]=branch(pthq_26_1,qmtot(27),tamb,linevec_27_1,contvec);
[p,h,rho,v,ve_27_2,msg,pthq_27_2]=branch(pthq_27_1,   qm(27),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_27_3,msg,pthq_27_3]=branch(pthq_27_2,   qm(27),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_26_4,msg,pthq_27_4]=branch(pthq_27_3,   qm(27),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_27_5,msg,pthq_27_5]=branch(pthq_27_4,   qm(27),tamb,linevec_99_5,contvec);

[p,h,rho,v,ve_28_1,msg,pthq_28_1]=branch(pthq_27_1,qmtot(28),tamb,linevec_28_1,contvec);
[p,h,rho,v,ve_28_2,msg,pthq_28_2]=branch(pthq_28_1,   qm(28),tamb,linevec_99_2,contvec);
[p,h,rho,v,ve_28_3,msg,pthq_28_3]=branch(pthq_28_2,   qm(28),tamb,linevec_99_3,contvec);
[p,h,rho,v,ve_28_4,msg,pthq_28_4]=branch(pthq_28_3,   qm(28),tamb,linevec_99_4,contvec);
[p,h,rho,v,ve_28_5,msg,pthq_28_5]=branch(pthq_28_4,   qm(28),tamb,linevec_99_5,contvec);

%start returns
[p,h,rho,v,ve_28_6,msg,pthq_28_6]=branch(pthq_28_5,qmtot(28),tamb,linevec_28_6,contvec);

hu_27_6=(pthq_28_6(3)*qmtot(28)+pthq_27_5(3)*qm(27))/(qmtot(28)+qm(27));
pthqu_27_6=[pthq_28_6(1),hu_27_6/4180.+273.16,hu_27_6,0.0];
[p,h,rho,v,ve_27_6,msg,pthq_27_6]=branch(pthqu_27_6,qmtot(27),tamb,linevec_27_6,contvec);

hu_26_6=(pthq_27_6(3)*qmtot(27)+pthq_26_5(3)*qm(26))/(qmtot(27)+qm(26));
pthqu_26_6=[pthq_27_6(1),hu_26_6/4180.+273.16,hu_26_6,0.0];
[p,h,rho,v,ve_26_6,msg,pthq_26_6]=branch(pthqu_26_6,qmtot(26),tamb,linevec_26_6,contvec);

hu_25_6=(pthq_26_6(3)*qmtot(26)+pthq_25_5(3)*qm(25))/(qmtot(26)+qm(25));
pthqu_25_6=[pthq_26_6(1),hu_25_6/4180.+273.16,hu_25_6,0.0];
[p,h,rho,v,ve_25_6,msg,pthq_25_6]=branch(pthqu_25_6,qmtot(25),tamb,linevec_25_6,contvec);

hu_24_6=(pthq_25_6(3)*qmtot(25)+pthq_24_5(3)*qm(24))/(qmtot(25)+qm(24));
pthqu_24_6=[pthq_25_6(1),hu_24_6/4180.+273.16,hu_24_6,0.0];
[p,h,rho,v,ve_24_6,msg,pthq_24_6]=branch(pthqu_24_6,qmtot(24),tamb,linevec_24_6,contvec);

hu_23_6=(pthq_24_6(3)*qmtot(24)+pthq_23_5(3)*qm(23))/(qmtot(24)+qm(23));
pthqu_23_6=[pthq_24_6(1),hu_23_6/4180.+273.16,hu_23_6,0.0];
[p,h,rho,v,ve_23_6,msg,pthq_23_6]=branch(pthqu_23_6,qmtot(23),tamb,linevec_23_6,contvec);
```

```
hu_22_6=(pthq_23_6(3)*qmtot(23)+pthq_22_5(3)*qm(22))/(qmtot(23)+qm(22));
pthqu_22_6=[pthq_23_6(1),hu_22_6/4180.+273.16,hu_22_6,0.0];
[p,h,rho,v,ve_22_6,msg,pthq_22_6]=branch(pthqu_22_6,qmtot(22),tamb,linevec_22_6,contvec);

hu_21_6=(pthq_22_6(3)*qmtot(22)+pthq_21_5(3)*qm(21))/(qmtot(22)+qm(21));
pthqu_21_6=[pthq_22_6(1),hu_21_6/4180.+273.16,hu_21_6,0.0];
[p,h,rho,v,ve_21_6,msg,pthq_21_6]=branch(pthqu_21_6,qmtot(21),tamb,linevec_21_6,contvec);

hu_20_6=(pthq_21_6(3)*qmtot(21)+pthq_20_5(3)*qm(20))/(qmtot(21)+qm(20));
pthqu_20_6=[pthq_21_6(1),hu_20_6/4180.+273.16,hu_20_6,0.0];
[p,h,rho,v,ve_20_6,msg,pthq_20_6]=branch(pthqu_20_6,qmtot(20),tamb,linevec_20_6,contvec);

hu_19_6=(pthq_20_6(3)*qmtot(20)+pthq_19_5(3)*qm(19))/(qmtot(20)+qm(19));
pthqu_19_6=[pthq_20_6(1),hu_19_6/4180.+273.16,hu_19_6,0.0];
[p,h,rho,v,ve_19_6,msg,pthq_19_6]=branch(pthqu_19_6,qmtot(19),tamb,linevec_19_6,contvec);

hu_18_6=(pthq_19_6(3)*qmtot(19)+pthq_18_5(3)*qm(18))/(qmtot(19)+qm(18));
pthqu_18_6=[pthq_19_6(1),hu_18_6/4180.+273.16,hu_18_6,0.0];
[p,h,rho,v,ve_18_6,msg,pthq_18_6]=branch(pthqu_18_6,qmtot(18),tamb,linevec_18_6,contvec);

hu_17_6=(pthq_18_6(3)*qmtot(18)+pthq_17_5(3)*qm(17))/(qmtot(18)+qm(17));
pthqu_17_6=[pthq_18_6(1),hu_17_6/4180.+273.16,hu_17_6,0.0];
[p,h,rho,v,ve_17_6,msg,pthq_17_6]=branch(pthqu_17_6,qmtot(17),tamb,linevec_17_6,contvec);

hu_16_6=(pthq_17_6(3)*qmtot(17)+pthq_16_5(3)*qm(16))/(qmtot(17)+qm(16));
pthqu_16_6=[pthq_17_6(1),hu_16_6/4180.+273.16,hu_16_6,0.0];
[p,h,rho,v,ve_16_6,msg,pthq_16_6]=branch(pthqu_16_6,qmtot(16),tamb,linevec_16_6,contvec);

hu_15_6=(pthq_16_6(3)*qmtot(16)+pthq_15_5(3)*qm(15))/(qmtot(16)+qm(15));
pthqu_15_6=[pthq_16_6(1),hu_15_6/4180.+273.16,hu_15_6,0.0];
[p,h,rho,v,ve_15_6,msg,pthq_15_6]=branch(pthqu_15_6,qmtot(15),tamb,linevec_15_6,contvec);

hu_14_6=(pthq_15_6(3)*qmtot(15)+pthq_14_5(3)*qm(14))/(qmtot(15)+qm(14));
pthqu_14_6=[pthq_15_6(1),hu_14_6/4180.+273.16,hu_14_6,0.0];
[p,h,rho,v,ve_14_6,msg,pthq_14_6]=branch(pthqu_14_6,qmtot(14),tamb,linevec_14_6,contvec);
```

```
hu_13_6=(pthq_14_6(3)*qmtot(14)+pthq_13_5(3)*qm(13))/(qmtot(14)+qm(13));
pthqu_13_6=[pthq_14_6(1),hu_13_6/4180.+273.16,hu_13_6,0.0];
[p,h,rho,v,ve_13_6,msg,pthq_13_6]=branch(pthqu_13_6,qmtot(13),tamb,linevec_13_6,contvec);

hu_12_6=(pthq_13_6(3)*qmtot(13)+pthq_12_5(3)*qm(12))/(qmtot(13)+qm(12));
pthqu_12_6=[pthq_13_6(1),hu_12_6/4180.+273.16,hu_12_6,0.0];
[p,h,rho,v,ve_12_6,msg,pthq_12_6]=branch(pthqu_12_6,qmtot(12),tamb,linevec_12_6,contvec);

hu_11_6=(pthq_12_6(3)*qmtot(12)+pthq_11_5(3)*qm(11))/(qmtot(12)+qm(11));
pthqu_11_6=[pthq_12_6(1),hu_11_6/4180.+273.16,hu_11_6,0.0];
[p,h,rho,v,ve_11_6,msg,pthq_11_6]=branch(pthqu_11_6,qmtot(11),tamb,linevec_11_6,contvec);

hu_10_6=(pthq_11_6(3)*qmtot(11)+pthq_10_5(3)*qm(10))/(qmtot(11)+qm(10));
pthqu_10_6=[pthq_11_6(1),hu_10_6/4180.+273.16,hu_10_6,0.0];
[p,h,rho,v,ve_10_6,msg,pthq_10_6]=branch(pthqu_10_6,qmtot(10),tamb,linevec_10_6,contvec);

hu_09_6=(pthq_10_6(3)*qmtot(10)+pthq_09_5(3)*qm(09))/(qmtot(10)+qm(09));
pthqu_09_6=[pthq_10_6(1),hu_09_6/4180.+273.16,hu_09_6,0.0];
[p,h,rho,v,ve_09_6,msg,pthq_09_6]=branch(pthqu_09_6,qmtot(09),tamb,linevec_09_6,contvec);

hu_08_6=(pthq_09_6(3)*qmtot(09)+pthq_08_5(3)*qm(08))/(qmtot(09)+qm(08));
pthqu_08_6=[pthq_09_6(1),hu_08_6/4180.+273.16,hu_08_6,0.0];
[p,h,rho,v,ve_08_6,msg,pthq_08_6]=branch(pthqu_08_6,qmtot(08),tamb,linevec_08_6,contvec);

hu_07_6=(pthq_08_6(3)*qmtot(08)+pthq_07_5(3)*qm(07))/(qmtot(08)+qm(07));
pthqu_07_6=[pthq_08_6(1),hu_07_6/4180.+273.16,hu_07_6,0.0];
[p,h,rho,v,ve_07_6,msg,pthq_07_6]=branch(pthqu_07_6,qmtot(07),tamb,linevec_07_6,contvec);

hu_06_6=(pthq_07_6(3)*qmtot(07)+pthq_06_5(3)*qm(06))/(qmtot(07)+qm(06));
pthqu_06_6=[pthq_07_6(1),hu_06_6/4180.+273.16,hu_06_6,0.0];
[p,h,rho,v,ve_06_6,msg,pthq_06_6]=branch(pthqu_06_6,qmtot(06),tamb,linevec_06_6,contvec);

hu_05_6=(pthq_06_6(3)*qmtot(06)+pthq_05_5(3)*qm(05))/(qmtot(06)+qm(05));
pthqu_05_6=[pthq_06_6(1),hu_05_6/4180.+273.16,hu_05_6,0.0];
[p,h,rho,v,ve_05_6,msg,pthq_05_6]=branch(pthqu_05_6,qmtot(05),tamb,linevec_05_6,contvec);
```

```
hu_04_6=(pthq_05_6(3)*qmtot(05)+pthq_04_5(3)*qm(04))/(qmtot(05)+qm(04));
pthqu_04_6=[pthq_05_6(1),hu_04_6/4180.+273.16,hu_04_6,0.0];
[p,h,rho,v,ve_04_6,msg,pthq_04_6]=branch(pthqu_04_6,qmtot(04),tamb,linevec_04_6,contvec);

hu_03_6=(pthq_04_6(3)*qmtot(04)+pthq_03_5(3)*qm(03))/(qmtot(04)+qm(03));
pthqu_03_6=[pthq_04_6(1),hu_03_6/4180.+273.16,hu_03_6,0.0];
[p,h,rho,v,ve_03_6,msg,pthq_03_6]=branch(pthqu_03_6,qmtot(03),tamb,linevec_03_6,contvec);

hu_02_6=(pthq_03_6(3)*qmtot(03)+pthq_02_5(3)*qm(2))/(qmtot(03)+qm(2));
pthqu_02_6=[pthq_03_6(1),hu_02_6/4180.+273.16,hu_02_6,0.0];
[p,h,rho,v,ve_02_6,msg,pthq_02_6]=branch(pthqu_02_6,qmtot(2),tamb,linevec_02_6,contvec);

hu_01_6=(pthq_02_6(3)*qmtot(02)+pthq_01_5(3)*qm(1))/(qmtot(02)+qm(1));
pthqu_01_6=[pthq_02_6(1),hu_01_6/4180.+273.16,hu_01_6,0.0];
[p,h,rho,v,ve_01_6,msg,pthq_01_6]=branch(pthqu_01_6,qmtot(1),tamb,linevec_01_6,contvec);

[p,h,rho,v,ve_00_2,msg,pthq_00_2]=branch(pthq_01_6,qmtot(1),tamb,linevec_00_2,contvec);

tvlvu=[...
    pthq_01_4(2);...
    pthq_02_4(2);...
    pthq_03_4(2);...
    pthq_04_4(2);...
    pthq_05_4(2);...
    pthq_06_4(2);...
    pthq_07_4(2);...
    pthq_08_4(2);...
    pthq_09_4(2);...
    pthq_10_4(2);...
    pthq_11_4(2);...
    pthq_12_4(2);...
    pthq_13_4(2);...
    pthq_14_4(2);...
    pthq_15_4(2);...
    pthq_16_4(2);...
    pthq_17_4(2);...
    pthq_18_4(2);...
```

```
    pthq_19_4(2);...
    pthq_20_4(2);...
    pthq_21_4(2);...
    pthq_22_4(2);...
    pthq_23_4(2);...
    pthq_24_4(2);...
    pthq_25_4(2);...
    pthq_26_4(2);...
    pthq_27_4(2);...
    pthq_28_4(2);...
    ];
```

postprocess.m

```
%Use it after fcvsystem.m or solversystem.m has been run to plot results
%to list results on command window and to write the 'result.txt' output file
floors = [-1:1:28];
floors2= [1:1:28];
t_risers=[...
   t_tmv,...
   pthq_00_1(2),...
   pthq_01_1(2),...
   pthq_02_1(2),...
   pthq_03_1(2),...
   pthq_04_1(2),...
   pthq_05_1(2),...
   pthq_06_1(2),...
   pthq_07_1(2),...
   pthq_08_1(2),...
   pthq_09_1(2),...
   pthq_10_1(2),...
   pthq_11_1(2),...
   pthq_12_1(2),...
   pthq_13_1(2),...
   pthq_14_1(2),...
   pthq_15_1(2),...
   pthq_16_1(2),...
   pthq_17_1(2),...
   pthq_18_1(2),...
   pthq_19_1(2),...
   pthq_20_1(2),...
   pthq_21_1(2),...
   pthq_22_1(2),...
   pthq_23_1(2),...
   pthq_24_1(2),...
   pthq_25_1(2),...
   pthq_26_1(2),...
   pthq_27_1(2),...
```

```
   pthq_28_1(2),...
   ];
t_return=[...
   pthq_00_2(2),...
   pthq_01_6(2),...
   pthqu_01_6(2),...
   pthqu_02_6(2),...
   pthqu_03_6(2),...
   pthqu_04_6(2),...
   pthqu_05_6(2),...
   pthqu_06_6(2),...
   pthqu_07_6(2),...
   pthqu_08_6(2),...
   pthqu_09_6(2),...
   pthqu_10_6(2),...
   pthqu_11_6(2),...
   pthqu_12_6(2),...
   pthqu_13_6(2),...
   pthqu_14_6(2),...
   pthqu_15_6(2),...
   pthqu_16_6(2),...
   pthqu_17_6(2),...
   pthqu_18_6(2),...
   pthqu_19_6(2),...
   pthqu_20_6(2),...
   pthqu_21_6(2),...
   pthqu_22_6(2),...
   pthqu_23_6(2),...
   pthqu_24_6(2),...
   pthqu_25_6(2),...
   pthqu_26_6(2),...
   pthqu_27_6(2),...
   pthq_28_5(2),...
   ];
t_valveu=[...
   pthq_01_4(2),...
   pthq_02_4(2),...
   pthq_03_4(2),...
```

```
   pthq_04_4(2),...
   pthq_05_4(2),...
   pthq_06_4(2),...
   pthq_07_4(2),...
   pthq_08_4(2),...
   pthq_09_4(2),...
   pthq_10_4(2),...
   pthq_11_4(2),...
   pthq_12_4(2),...
   pthq_13_4(2),...
   pthq_14_4(2),...
   pthq_15_4(2),...
   pthq_16_4(2),...
   pthq_17_4(2),...
   pthq_18_4(2),...
   pthq_19_4(2),...
   pthq_20_4(2),...
   pthq_21_4(2),...
   pthq_22_4(2),...
   pthq_23_4(2),...
   pthq_24_4(2),...
   pthq_25_4(2),...
   pthq_26_4(2),...
   pthq_27_4(2),...
   pthq_28_4(2),...
   ];

%plot temperature as a function of floors, for risers and returns
figure(31);
clf;
plot(floors,(t_risers-273.16)*1.8+32.,'r-','linewidth',2);
hold on;
plot(floors,(t_return-273.16)*1.8+32.,'b-','linewidth',2);
grid on;
title('Temperature in risers and returns')
legend('risers','returns',4);
xlabel('floors');
```

```
ylabel('Temperature');
axis([-1,max(floors),113.,120.]);

%plot fcv valve upstream temperature as a function of floors
figure(32);
clf;
plot(floors2,(t_valveu-273.16)*1.8+32.,'r-','linewidth',2);
grid on;
title('Fcv valve upstream temperature');
xlabel('floors');
ylabel('Temperature');
axis([1,max(floors2),114.,120.]);

%plot temperature as a function of location on each floor, for each floor
floorloc=[0,1,2,3,4];
figure(33)
clf;
plot(floorloc,([pthq_01_1(2),pthq_01_2(2),pthq_01_3(2),pthq_01_4(2),pthq_01_5(2)]-273.16)*1.8+32.,'k-
','linewidth',2);
%ht=text(3,(pthq_01_4(2)-273.16)*1.8+32.005,'01');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_02_1(2),pthq_02_2(2),pthq_02_3(2),pthq_02_4(2),pthq_02_5(2)]-273.16)*1.8+32.,'g-
','linewidth',2);
%ht=text(3,(pthq_02_4(2)-273.16)*1.8+32.005,'02');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_03_1(2),pthq_03_2(2),pthq_03_3(2),pthq_03_4(2),pthq_03_5(2)]-273.16)*1.8+32.,'r-
','linewidth',2);
%ht=text(3,(pthq_03_4(2)-273.16)*1.8+32.005,'03');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_04_1(2),pthq_04_2(2),pthq_04_3(2),pthq_04_4(2),pthq_04_5(2)]-273.16)*1.8+32.,'b-
','linewidth',2);
%ht=text(3,(pthq_04_4(2)-273.16)*1.8+32.005,'04');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_05_1(2),pthq_05_2(2),pthq_05_3(2),pthq_05_4(2),pthq_05_5(2)]-273.16)*1.8+32.,'-
','color',[1,.85,0],'linewidth',2);
%ht=text(3,(pthq_05_4(2)-273.16)*1.8+32.005,'05');set(ht,'fontsize',8);
hold on;
```

```
plot(floorloc,([pthq_06_1(2),pthq_06_2(2),pthq_06_3(2),pthq_06_4(2),pthq_06_5(2)]-273.16)*1.8+32.,'c-
','linewidth',2);
%ht=text(3,(pthq_06_4(2)-273.16)*1.8+32.005,'06');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_07_1(2),pthq_07_2(2),pthq_07_3(2),pthq_07_4(2),pthq_07_5(2)]-273.16)*1.8+32.,'m-
','linewidth',2);
%ht=text(3,(pthq_07_4(2)-273.16)*1.8+32.005,'07');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_08_1(2),pthq_08_2(2),pthq_08_3(2),pthq_08_4(2),pthq_08_5(2)]-273.16)*1.8+32.,'k-
','linewidth',2);
%ht=text(3,(pthq_08_4(2)-273.16)*1.8+32.005,'08');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_09_1(2),pthq_09_2(2),pthq_09_3(2),pthq_09_4(2),pthq_09_5(2)]-273.16)*1.8+32.,'g-
','linewidth',2);
%ht=text(3,(pthq_09_4(2)-273.16)*1.8+32.005,'09');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_10_1(2),pthq_10_2(2),pthq_10_3(2),pthq_10_4(2),pthq_10_5(2)]-273.16)*1.8+32.,'r-
','linewidth',2);
%ht=text(3,(pthq_10_4(2)-273.16)*1.8+32.005,'10');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_11_1(2),pthq_11_2(2),pthq_11_3(2),pthq_11_4(2),pthq_11_5(2)]-273.16)*1.8+32.,'b-
','linewidth',2);
%ht=text(3,(pthq_11_4(2)-273.16)*1.8+32.005,'11');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_12_1(2),pthq_12_2(2),pthq_12_3(2),pthq_12_4(2),pthq_12_5(2)]-273.16)*1.8+32.,'-
','color',[1,.85,0],'linewidth',2);
%ht=text(3,(pthq_12_4(2)-273.16)*1.8+32.005,'12');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_13_1(2),pthq_13_2(2),pthq_13_3(2),pthq_13_4(2),pthq_13_5(2)]-273.16)*1.8+32.,'c-
','linewidth',2);
%ht=text(3,(pthq_13_4(2)-273.16)*1.8+32.005,'13');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_14_1(2),pthq_14_2(2),pthq_14_3(2),pthq_14_4(2),pthq_14_5(2)]-273.16)*1.8+32.,'m-
','linewidth',2);
%ht=text(3,(pthq_14_4(2)-273.16)*1.8+32.005,'14');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_15_1(2),pthq_15_2(2),pthq_15_3(2),pthq_15_4(2),pthq_15_5(2)]-273.16)*1.8+32.,'k-
','linewidth',2);
```

```
%ht=text(3,(pthq_15_4(2)-273.16)*1.8+32.005,'15');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_16_1(2),pthq_16_2(2),pthq_16_3(2),pthq_16_4(2),pthq_16_5(2)]-273.16)*1.8+32.,'g-
','linewidth',2);
%ht=text(3,(pthq_16_4(2)-273.16)*1.8+32.005,'16');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_17_1(2),pthq_17_2(2),pthq_17_3(2),pthq_17_4(2),pthq_17_5(2)]-273.16)*1.8+32.,'r-
','linewidth',2);
%ht=text(3,(pthq_17_4(2)-273.16)*1.8+32.005,'17');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_18_1(2),pthq_18_2(2),pthq_18_3(2),pthq_18_4(2),pthq_18_5(2)]-273.16)*1.8+32.,'b-
','linewidth',2);
%ht=text(3,(pthq_18_4(2)-273.16)*1.8+32.005,'18');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_19_1(2),pthq_19_2(2),pthq_19_3(2),pthq_19_4(2),pthq_19_5(2)]-273.16)*1.8+32.,'-
','color',[1,.85,0],'linewidth',2);
%ht=text(3,(pthq_19_4(2)-273.16)*1.8+32.005,'19');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_20_1(2),pthq_20_2(2),pthq_20_3(2),pthq_20_4(2),pthq_20_5(2)]-273.16)*1.8+32.,'c-
','linewidth',2);
%ht=text(3,(pthq_20_4(2)-273.16)*1.8+32.005,'20');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_21_1(2),pthq_21_2(2),pthq_21_3(2),pthq_21_4(2),pthq_21_5(2)]-273.16)*1.8+32.,'m-
','linewidth',2);
%ht=text(3,(pthq_21_4(2)-273.16)*1.8+32.005,'21');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_22_1(2),pthq_22_2(2),pthq_22_3(2),pthq_22_4(2),pthq_22_5(2)]-273.16)*1.8+32.,'k-
','linewidth',2);
%ht=text(3,(pthq_22_4(2)-273.16)*1.8+32.005,'22');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_23_1(2),pthq_23_2(2),pthq_23_3(2),pthq_23_4(2),pthq_23_5(2)]-273.16)*1.8+32.,'g-
','linewidth',2);
%ht=text(3,(pthq_23_4(2)-273.16)*1.8+32.005,'23');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_24_1(2),pthq_24_2(2),pthq_24_3(2),pthq_24_4(2),pthq_24_5(2)]-273.16)*1.8+32.,'r-
','linewidth',2);
%ht=text(3,(pthq_24_4(2)-273.16)*1.8+32.005,'24');set(ht,'fontsize',8);
hold on;
```

```
plot(floorloc,([pthq_25_1(2),pthq_25_2(2),pthq_25_3(2),pthq_25_4(2),pthq_25_5(2)]-273.16)*1.8+32.,'b-
','linewidth',2);
%ht=text(3,(pthq_25_4(2)-273.16)*1.8+32.005,'25');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_26_1(2),pthq_26_2(2),pthq_26_3(2),pthq_26_4(2),pthq_26_5(2)]-273.16)*1.8+32.,'-
','color',[1,.85,0],'linewidth',2);
%ht=text(3,(pthq_26_4(2)-273.16)*1.8+32.005,'26');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_27_1(2),pthq_27_2(2),pthq_27_3(2),pthq_27_4(2),pthq_27_5(2)]-273.16)*1.8+32.,'c-
','linewidth',2);
%ht=text(3,(pthq_27_4(2)-273.16)*1.8+32.005,'27');set(ht,'fontsize',8);
hold on;
plot(floorloc,([pthq_28_1(2),pthq_28_2(2),pthq_28_3(2),pthq_28_4(2),pthq_28_5(2)]-273.16)*1.8+32.,'m-
','linewidth',2);
%ht=text(3,(pthq_28_4(2)-273.16)*1.8+32.005,'28');set(ht,'fontsize',8);
grid on;
title('Temperature distribution on the floors');
legend('floor 01','floor 02','floor 03','floor 04','floor 05','floor 06','floor 07',3);
xlabel('Location - node');
ylabel('Temperature deg K');
axis([0 4.0 114. 120.]);


%heat loss calculation
qloss1 = 0.0...  %all risers
    +pthq_00_1(4)...
    +pthq_01_1(4)...
    +pthq_02_1(4)...
    +pthq_03_1(4)...
    +pthq_04_1(4)...
    +pthq_05_1(4)...
    +pthq_06_1(4)...
    +pthq_07_1(4)...
    +pthq_08_1(4)...
    +pthq_09_1(4)...
    +pthq_10_1(4)...
    +pthq_11_1(4)...
```

```
    +pthq_12_1(4)...
    +pthq_13_1(4)...
    +pthq_14_1(4)...
    +pthq_15_1(4)...
    +pthq_16_1(4)...
    +pthq_17_1(4)...
    +pthq_18_1(4)...
    +pthq_19_1(4)...
    +pthq_20_1(4)...
    +pthq_21_1(4)...
    +pthq_22_1(4)...
    +pthq_23_1(4)...
    +pthq_24_1(4)...
    +pthq_25_1(4)...
    +pthq_26_1(4)...
    +pthq_27_1(4)...
    +pthq_28_1(4)...
    ;

qloss2 = 0.0...  %all floors before valves
    +pthq_01_2(4)+pthq_01_3(4)+pthq_01_4(4)...
    +pthq_02_2(4)+pthq_02_3(4)+pthq_02_4(4)...
    +pthq_03_2(4)+pthq_03_3(4)+pthq_03_4(4)...
    +pthq_04_2(4)+pthq_04_3(4)+pthq_04_4(4)...
    +pthq_05_2(4)+pthq_05_3(4)+pthq_05_4(4)...
    +pthq_06_2(4)+pthq_06_3(4)+pthq_06_4(4)...
    +pthq_07_2(4)+pthq_07_3(4)+pthq_07_4(4)...
    +pthq_08_2(4)+pthq_08_3(4)+pthq_08_4(4)...
    +pthq_09_2(4)+pthq_09_3(4)+pthq_09_4(4)...
    +pthq_10_2(4)+pthq_10_3(4)+pthq_10_4(4)...
    +pthq_11_2(4)+pthq_11_3(4)+pthq_11_4(4)...
    +pthq_12_2(4)+pthq_12_3(4)+pthq_12_4(4)...
    +pthq_13_2(4)+pthq_13_3(4)+pthq_13_4(4)...
    +pthq_14_2(4)+pthq_14_3(4)+pthq_14_4(4)...
    +pthq_15_2(4)+pthq_15_3(4)+pthq_15_4(4)...
    +pthq_16_2(4)+pthq_16_3(4)+pthq_16_4(4)...
    +pthq_17_2(4)+pthq_17_3(4)+pthq_17_4(4)...
```

```
    +pthq_18_2(4)+pthq_18_3(4)+pthq_18_4(4)...
    +pthq_19_2(4)+pthq_19_3(4)+pthq_19_4(4)...
    +pthq_20_2(4)+pthq_20_3(4)+pthq_20_4(4)...
    +pthq_21_2(4)+pthq_21_3(4)+pthq_21_4(4)...
    +pthq_22_2(4)+pthq_22_3(4)+pthq_22_4(4)...
    +pthq_23_2(4)+pthq_23_3(4)+pthq_23_4(4)...
    +pthq_24_2(4)+pthq_24_3(4)+pthq_24_4(4)...
    +pthq_25_2(4)+pthq_25_3(4)+pthq_25_4(4)...
    +pthq_26_2(4)+pthq_26_3(4)+pthq_26_4(4)...
    +pthq_27_2(4)+pthq_27_3(4)+pthq_27_4(4)...
    +pthq_28_2(4)+pthq_28_3(4)+pthq_28_4(4)...
    ;

qloss3 = 0.0...  %all returns
    +pthq_00_2(4)...
    +pthq_01_5(4)+pthq_01_6(4)...
    +pthq_02_5(4)+pthq_02_6(4)...
    +pthq_03_5(4)+pthq_03_6(4)...
    +pthq_04_5(4)+pthq_04_6(4)...
    +pthq_05_5(4)+pthq_05_6(4)...
    +pthq_06_5(4)+pthq_06_6(4)...
    +pthq_07_5(4)+pthq_07_6(4)...
    +pthq_08_5(4)+pthq_08_6(4)...
    +pthq_09_5(4)+pthq_09_6(4)...
    +pthq_10_5(4)+pthq_10_6(4)...
    +pthq_11_5(4)+pthq_11_6(4)...
    +pthq_12_5(4)+pthq_12_6(4)...
    +pthq_13_5(4)+pthq_13_6(4)...
    +pthq_14_5(4)+pthq_14_6(4)...
    +pthq_15_5(4)+pthq_15_6(4)...
    +pthq_16_5(4)+pthq_16_6(4)...
    +pthq_17_5(4)+pthq_17_6(4)...
    +pthq_18_5(4)+pthq_18_6(4)...
    +pthq_19_5(4)+pthq_19_6(4)...
    +pthq_20_5(4)+pthq_20_6(4)...
    +pthq_21_5(4)+pthq_21_6(4)...
    +pthq_22_5(4)+pthq_22_6(4)...
```

```
    +pthq_23_5(4)+pthq_23_6(4)...
    +pthq_24_5(4)+pthq_24_6(4)...
    +pthq_25_5(4)+pthq_25_6(4)...
    +pthq_26_5(4)+pthq_26_6(4)...
    +pthq_27_5(4)+pthq_27_6(4)...
    +pthq_28_5(4)+pthq_28_6(4)...
    ;

qloss_total = qloss1+qloss2+qloss3;
hin = qmtot(1)*h_tmv;
hout= qmtot(1)*pthq_00_2(3);

disp(' ');disp(' ');
disp(strcat('Sum of heat loss rates in all pipes [BTU/hr]:
=',num2str(qloss_total*3.4152)));
disp(strcat('Difference between enthalpy in and out [BTU/hr]:                    =',num2str((hin-
hout)*3.4152)));
disp(strcat('Sum of heat loss rates in all pipes upstream of valves [BTU/hr]:
=',num2str((qloss1+qloss2)*3.4152)));

'Valve upstream temperatures:'
[(1:1:28)', ((t_valveu-273.16)*1.8+32)']

'Valve flow rates:'
[(1:1:28)', qm/1000./3.7854e-3*60]

%write tabulated result in text file
fid= fopen('results.txt','w');
fprintf(fid,'_00_1: %7.2f, %7.2f, %7.3f, %7.3f\n',(t_tmv-273.16)*1.8+32.,(pthq_00_1(2)-
273.16)*1.8+32.,ve_00_1/.3048,pthq_00_1(4)*3.4152);
fprintf(fid,'_00_2: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthq_01_6(2)-273.16)*1.8+32.,(pthq_00_2(2)-
273.16)*1.8+32.,ve_01_6/.3048,pthq_00_2(4)*3.4152);
 %floor _01
fprintf(fid,'_01_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_00_1(2)-273.16)*1.8+32.,(pthq_01_1(2)-
273.16)*1.8+32.,ve_00_1/.3048,pthq_01_1(4)*3.4152);
fprintf(fid,'_01_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_01_1(2)-273.16)*1.8+32.,(pthq_01_2(2)-
273.16)*1.8+32.,ve_01_2/.3048,pthq_01_2(4)*3.4152);
```

```
fprintf(fid,'_01_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_01_2(2)-273.16)*1.8+32.,(pthq_01_3(2)-
273.16)*1.8+32.,ve_01_3/.3048,pthq_01_3(4)*3.4152);
fprintf(fid,'_01_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_01_3(2)-273.16)*1.8+32.,(pthq_01_4(2)-
273.16)*1.8+32.,ve_01_4/.3048,pthq_01_4(4)*3.4152);
fprintf(fid,'_01_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_01_4(2)-273.16)*1.8+32.,(pthq_01_5(2)-
273.16)*1.8+32.,ve_01_5/.3048,pthq_01_5(4)*3.4152);
fprintf(fid,'_01_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_01_6(2)-273.16)*1.8+32.,(pthq_01_6(2)-
273.16)*1.8+32.,ve_01_6/.3048,pthq_01_6(4)*3.4152);
 %floor _02
fprintf(fid,'_02_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_01_1(2)-273.16)*1.8+32.,(pthq_02_1(2)-
273.16)*1.8+32.,ve_02_1/.3048,pthq_02_1(4)*3.4152);
fprintf(fid,'_02_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_02_1(2)-273.16)*1.8+32.,(pthq_02_2(2)-
273.16)*1.8+32.,ve_02_2/.3048,pthq_02_2(4)*3.4152);
fprintf(fid,'_02_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_02_2(2)-273.16)*1.8+32.,(pthq_02_3(2)-
273.16)*1.8+32.,ve_02_3/.3048,pthq_02_3(4)*3.4152);
fprintf(fid,'_02_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_02_3(2)-273.16)*1.8+32.,(pthq_02_4(2)-
273.16)*1.8+32.,ve_02_4/.3048,pthq_02_4(4)*3.4152);
fprintf(fid,'_02_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_02_4(2)-273.16)*1.8+32.,(pthq_02_5(2)-
273.16)*1.8+32.,ve_02_5/.3048,pthq_02_5(4)*3.4152);
fprintf(fid,'_02_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_02_6(2)-273.16)*1.8+32.,(pthq_02_6(2)-
273.16)*1.8+32.,ve_02_6/.3048,pthq_02_6(4)*3.4152);
 %floor _03
fprintf(fid,'_03_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_02_1(2)-273.16)*1.8+32.,(pthq_03_1(2)-
273.16)*1.8+32.,ve_03_1/.3048,pthq_03_1(4)*3.4152);
fprintf(fid,'_03_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_03_1(2)-273.16)*1.8+32.,(pthq_03_2(2)-
273.16)*1.8+32.,ve_03_2/.3048,pthq_03_2(4)*3.4152);
fprintf(fid,'_03_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_03_2(2)-273.16)*1.8+32.,(pthq_03_3(2)-
273.16)*1.8+32.,ve_03_3/.3048,pthq_03_3(4)*3.4152);
fprintf(fid,'_03_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_03_3(2)-273.16)*1.8+32.,(pthq_03_4(2)-
273.16)*1.8+32.,ve_03_4/.3048,pthq_03_4(4)*3.4152);
fprintf(fid,'_03_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_03_4(2)-273.16)*1.8+32.,(pthq_03_5(2)-
273.16)*1.8+32.,ve_03_5/.3048,pthq_03_5(4)*3.4152);
fprintf(fid,'_03_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_03_6(2)-273.16)*1.8+32.,(pthq_03_6(2)-
273.16)*1.8+32.,ve_03_6/.3048,pthq_03_6(4)*3.4152);
 %floor _04
fprintf(fid,'_04_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_03_1(2)-273.16)*1.8+32.,(pthq_04_1(2)-
273.16)*1.8+32.,ve_04_1/.3048,pthq_04_1(4)*3.4152);
```

```
fprintf(fid,'_04_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_04_1(2)-273.16)*1.8+32.,(pthq_04_2(2)-
273.16)*1.8+32.,ve_04_2/.3048,pthq_04_2(4)*3.4152);
fprintf(fid,'_04_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_04_2(2)-273.16)*1.8+32.,(pthq_04_3(2)-
273.16)*1.8+32.,ve_04_3/.3048,pthq_04_3(4)*3.4152);
fprintf(fid,'_04_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_04_3(2)-273.16)*1.8+32.,(pthq_04_4(2)-
273.16)*1.8+32.,ve_04_4/.3048,pthq_04_4(4)*3.4152);
fprintf(fid,'_04_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_04_4(2)-273.16)*1.8+32.,(pthq_04_5(2)-
273.16)*1.8+32.,ve_04_5/.3048,pthq_04_5(4)*3.4152);
fprintf(fid,'_04_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_04_6(2)-273.16)*1.8+32.,(pthq_04_6(2)-
273.16)*1.8+32.,ve_04_6/.3048,pthq_04_6(4)*3.4152);
 %floor _05
fprintf(fid,'_05_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_04_1(2)-273.16)*1.8+32.,(pthq_05_1(2)-
273.16)*1.8+32.,ve_05_1/.3048,pthq_05_1(4)*3.4152);
fprintf(fid,'_05_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_05_1(2)-273.16)*1.8+32.,(pthq_05_2(2)-
273.16)*1.8+32.,ve_05_2/.3048,pthq_05_2(4)*3.4152);
fprintf(fid,'_05_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_05_2(2)-273.16)*1.8+32.,(pthq_05_3(2)-
273.16)*1.8+32.,ve_05_3/.3048,pthq_05_3(4)*3.4152);
fprintf(fid,'_05_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_05_3(2)-273.16)*1.8+32.,(pthq_05_4(2)-
273.16)*1.8+32.,ve_05_4/.3048,pthq_05_4(4)*3.4152);
fprintf(fid,'_05_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_05_4(2)-273.16)*1.8+32.,(pthq_05_5(2)-
273.16)*1.8+32.,ve_05_5/.3048,pthq_05_5(4)*3.4152);
fprintf(fid,'_05_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_05_6(2)-273.16)*1.8+32.,(pthq_05_6(2)-
273.16)*1.8+32.,ve_05_6/.3048,pthq_05_6(4)*3.4152);
 %floor _06
fprintf(fid,'_06_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_05_1(2)-273.16)*1.8+32.,(pthq_06_1(2)-
273.16)*1.8+32.,ve_06_1/.3048,pthq_06_1(4)*3.4152);
fprintf(fid,'_06_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_06_1(2)-273.16)*1.8+32.,(pthq_06_2(2)-
273.16)*1.8+32.,ve_06_2/.3048,pthq_06_2(4)*3.4152);
fprintf(fid,'_06_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_06_2(2)-273.16)*1.8+32.,(pthq_06_3(2)-
273.16)*1.8+32.,ve_06_3/.3048,pthq_06_3(4)*3.4152);
fprintf(fid,'_06_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_06_3(2)-273.16)*1.8+32.,(pthq_06_4(2)-
273.16)*1.8+32.,ve_06_4/.3048,pthq_06_4(4)*3.4152);
fprintf(fid,'_06_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_06_4(2)-273.16)*1.8+32.,(pthq_06_5(2)-
273.16)*1.8+32.,ve_06_5/.3048,pthq_06_5(4)*3.4152);
fprintf(fid,'_06_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_06_6(2)-273.16)*1.8+32.,(pthq_06_6(2)-
273.16)*1.8+32.,ve_06_6/.3048,pthq_06_6(4)*3.4152);
 %floor _07
```

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fprintf(fid,'_07_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_06_1(2)-273.16)*1.8+32.,(pthq_07_1(2)-
273.16)*1.8+32.,ve_07_1/.3048,pthq_07_1(4)*3.4152);
fprintf(fid,'_07_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_07_1(2)-273.16)*1.8+32.,(pthq_07_2(2)-
273.16)*1.8+32.,ve_07_2/.3048,pthq_07_2(4)*3.4152);
fprintf(fid,'_07_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_07_2(2)-273.16)*1.8+32.,(pthq_07_3(2)-
273.16)*1.8+32.,ve_07_3/.3048,pthq_07_3(4)*3.4152);
fprintf(fid,'_07_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_07_3(2)-273.16)*1.8+32.,(pthq_07_4(2)-
273.16)*1.8+32.,ve_07_4/.3048,pthq_07_4(4)*3.4152);
fprintf(fid,'_07_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_07_4(2)-273.16)*1.8+32.,(pthq_07_5(2)-
273.16)*1.8+32.,ve_07_5/.3048,pthq_07_5(4)*3.4152);
fprintf(fid,'_07_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_07_6(2)-273.16)*1.8+32.,(pthq_07_6(2)-
273.16)*1.8+32.,ve_07_6/.3048,pthq_07_6(4)*3.4152);
 %floor _08
fprintf(fid,'_08_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_07_1(2)-273.16)*1.8+32.,(pthq_08_1(2)-
273.16)*1.8+32.,ve_08_1/.3048,pthq_08_1(4)*3.4152);
fprintf(fid,'_08_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_08_1(2)-273.16)*1.8+32.,(pthq_08_2(2)-
273.16)*1.8+32.,ve_08_2/.3048,pthq_08_2(4)*3.4152);
fprintf(fid,'_08_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_08_2(2)-273.16)*1.8+32.,(pthq_08_3(2)-
273.16)*1.8+32.,ve_08_3/.3048,pthq_08_3(4)*3.4152);
fprintf(fid,'_08_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_08_3(2)-273.16)*1.8+32.,(pthq_08_4(2)-
273.16)*1.8+32.,ve_08_4/.3048,pthq_08_4(4)*3.4152);
fprintf(fid,'_08_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_08_4(2)-273.16)*1.8+32.,(pthq_08_5(2)-
273.16)*1.8+32.,ve_08_5/.3048,pthq_08_5(4)*3.4152);
fprintf(fid,'_08_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_08_6(2)-273.16)*1.8+32.,(pthq_08_6(2)-
273.16)*1.8+32.,ve_08_6/.3048,pthq_08_6(4)*3.4152);
 %floor _09
fprintf(fid,'_09_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_08_1(2)-273.16)*1.8+32.,(pthq_09_1(2)-
273.16)*1.8+32.,ve_09_1/.3048,pthq_09_1(4)*3.4152);
fprintf(fid,'_09_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_09_1(2)-273.16)*1.8+32.,(pthq_09_2(2)-
273.16)*1.8+32.,ve_09_2/.3048,pthq_09_2(4)*3.4152);
fprintf(fid,'_09_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_09_2(2)-273.16)*1.8+32.,(pthq_09_3(2)-
273.16)*1.8+32.,ve_09_3/.3048,pthq_09_3(4)*3.4152);
fprintf(fid,'_09_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_09_3(2)-273.16)*1.8+32.,(pthq_09_4(2)-
273.16)*1.8+32.,ve_09_4/.3048,pthq_09_4(4)*3.4152);
fprintf(fid,'_09_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_09_4(2)-273.16)*1.8+32.,(pthq_09_5(2)-
273.16)*1.8+32.,ve_09_5/.3048,pthq_09_5(4)*3.4152);
fprintf(fid,'_09_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_09_6(2)-273.16)*1.8+32.,(pthq_09_6(2)-
273.16)*1.8+32.,ve_09_6/.3048,pthq_09_6(4)*3.4152);
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 %floor _10
fprintf(fid,'_10_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_09_1(2)-273.16)*1.8+32.,(pthq_10_1(2)-
273.16)*1.8+32.,ve_10_1/.3048,pthq_10_1(4)*3.4152);
fprintf(fid,'_10_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_10_1(2)-273.16)*1.8+32.,(pthq_10_2(2)-
273.16)*1.8+32.,ve_10_2/.3048,pthq_10_2(4)*3.4152);
fprintf(fid,'_10_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_10_2(2)-273.16)*1.8+32.,(pthq_10_3(2)-
273.16)*1.8+32.,ve_10_3/.3048,pthq_10_3(4)*3.4152);
fprintf(fid,'_10_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_10_3(2)-273.16)*1.8+32.,(pthq_10_4(2)-
273.16)*1.8+32.,ve_10_4/.3048,pthq_10_4(4)*3.4152);
fprintf(fid,'_10_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_10_4(2)-273.16)*1.8+32.,(pthq_10_5(2)-
273.16)*1.8+32.,ve_10_5/.3048,pthq_10_5(4)*3.4152);
fprintf(fid,'_10_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_10_6(2)-273.16)*1.8+32.,(pthq_10_6(2)-
273.16)*1.8+32.,ve_10_6/.3048,pthq_10_6(4)*3.4152);
 %floor _11
fprintf(fid,'_11_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_10_1(2)-273.16)*1.8+32.,(pthq_11_1(2)-
273.16)*1.8+32.,ve_11_1/.3048,pthq_11_1(4)*3.4152);
fprintf(fid,'_11_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_11_1(2)-273.16)*1.8+32.,(pthq_11_2(2)-
273.16)*1.8+32.,ve_11_2/.3048,pthq_11_2(4)*3.4152);
fprintf(fid,'_11_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_11_2(2)-273.16)*1.8+32.,(pthq_11_3(2)-
273.16)*1.8+32.,ve_11_3/.3048,pthq_11_3(4)*3.4152);
fprintf(fid,'_11_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_11_3(2)-273.16)*1.8+32.,(pthq_11_4(2)-
273.16)*1.8+32.,ve_11_4/.3048,pthq_11_4(4)*3.4152);
fprintf(fid,'_11_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_11_4(2)-273.16)*1.8+32.,(pthq_11_5(2)-
273.16)*1.8+32.,ve_11_5/.3048,pthq_11_5(4)*3.4152);
fprintf(fid,'_11_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_11_6(2)-273.16)*1.8+32.,(pthq_11_6(2)-
273.16)*1.8+32.,ve_11_6/.3048,pthq_11_6(4)*3.4152);
 %floor _12
fprintf(fid,'_12_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_11_1(2)-273.16)*1.8+32.,(pthq_12_1(2)-
273.16)*1.8+32.,ve_12_1/.3048,pthq_12_1(4)*3.4152);
fprintf(fid,'_12_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_12_1(2)-273.16)*1.8+32.,(pthq_12_2(2)-
273.16)*1.8+32.,ve_12_2/.3048,pthq_12_2(4)*3.4152);
fprintf(fid,'_12_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_12_2(2)-273.16)*1.8+32.,(pthq_12_3(2)-
273.16)*1.8+32.,ve_12_3/.3048,pthq_12_3(4)*3.4152);
fprintf(fid,'_12_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_12_3(2)-273.16)*1.8+32.,(pthq_12_4(2)-
273.16)*1.8+32.,ve_12_4/.3048,pthq_12_4(4)*3.4152);
fprintf(fid,'_12_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_12_4(2)-273.16)*1.8+32.,(pthq_12_5(2)-
273.16)*1.8+32.,ve_12_5/.3048,pthq_12_5(4)*3.4152);
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fprintf(fid,'_12_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_12_6(2)-273.16)*1.8+32.,(pthq_12_6(2)-
273.16)*1.8+32.,ve_12_6/.3048,pthq_12_6(4)*3.4152);
 %floor _13
fprintf(fid,'_13_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_12_1(2)-273.16)*1.8+32.,(pthq_13_1(2)-
273.16)*1.8+32.,ve_13_1/.3048,pthq_13_1(4)*3.4152);
fprintf(fid,'_13_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_13_1(2)-273.16)*1.8+32.,(pthq_13_2(2)-
273.16)*1.8+32.,ve_13_2/.3048,pthq_13_2(4)*3.4152);
fprintf(fid,'_13_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_13_2(2)-273.16)*1.8+32.,(pthq_13_3(2)-
273.16)*1.8+32.,ve_13_3/.3048,pthq_13_3(4)*3.4152);
fprintf(fid,'_13_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_13_3(2)-273.16)*1.8+32.,(pthq_13_4(2)-
273.16)*1.8+32.,ve_13_4/.3048,pthq_13_4(4)*3.4152);
fprintf(fid,'_13_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_13_4(2)-273.16)*1.8+32.,(pthq_13_5(2)-
273.16)*1.8+32.,ve_13_5/.3048,pthq_13_5(4)*3.4152);
fprintf(fid,'_13_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_13_6(2)-273.16)*1.8+32.,(pthq_13_6(2)-
273.16)*1.8+32.,ve_13_6/.3048,pthq_13_6(4)*3.4152);
 %floor _14
fprintf(fid,'_14_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_13_1(2)-273.16)*1.8+32.,(pthq_14_1(2)-
273.16)*1.8+32.,ve_14_1/.3048,pthq_14_1(4)*3.4152);
fprintf(fid,'_14_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_14_1(2)-273.16)*1.8+32.,(pthq_14_2(2)-
273.16)*1.8+32.,ve_14_2/.3048,pthq_14_2(4)*3.4152);
fprintf(fid,'_14_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_14_2(2)-273.16)*1.8+32.,(pthq_14_3(2)-
273.16)*1.8+32.,ve_14_3/.3048,pthq_14_3(4)*3.4152);
fprintf(fid,'_14_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_14_3(2)-273.16)*1.8+32.,(pthq_14_4(2)-
273.16)*1.8+32.,ve_14_4/.3048,pthq_14_4(4)*3.4152);
fprintf(fid,'_14_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_14_4(2)-273.16)*1.8+32.,(pthq_14_5(2)-
273.16)*1.8+32.,ve_14_5/.3048,pthq_14_5(4)*3.4152);
fprintf(fid,'_14_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_14_6(2)-273.16)*1.8+32.,(pthq_14_6(2)-
273.16)*1.8+32.,ve_14_6/.3048,pthq_14_6(4)*3.4152);
 %floor _15
fprintf(fid,'_15_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_14_1(2)-273.16)*1.8+32.,(pthq_15_1(2)-
273.16)*1.8+32.,ve_15_1/.3048,pthq_15_1(4)*3.4152);
fprintf(fid,'_15_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_15_1(2)-273.16)*1.8+32.,(pthq_15_2(2)-
273.16)*1.8+32.,ve_15_2/.3048,pthq_15_2(4)*3.4152);
fprintf(fid,'_15_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_15_2(2)-273.16)*1.8+32.,(pthq_15_3(2)-
273.16)*1.8+32.,ve_15_3/.3048,pthq_15_3(4)*3.4152);
fprintf(fid,'_15_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_15_3(2)-273.16)*1.8+32.,(pthq_15_4(2)-
273.16)*1.8+32.,ve_15_4/.3048,pthq_15_4(4)*3.4152);
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fprintf(fid,'_15_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_15_4(2)-273.16)*1.8+32.,(pthq_15_5(2)-
273.16)*1.8+32.,ve_15_5/.3048,pthq_15_5(4)*3.4152);
fprintf(fid,'_15_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_15_6(2)-273.16)*1.8+32.,(pthq_15_6(2)-
273.16)*1.8+32.,ve_15_6/.3048,pthq_15_6(4)*3.4152);
 %floor _16
fprintf(fid,'_16_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_15_1(2)-273.16)*1.8+32.,(pthq_16_1(2)-
273.16)*1.8+32.,ve_16_1/.3048,pthq_16_1(4)*3.4152);
fprintf(fid,'_16_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_16_1(2)-273.16)*1.8+32.,(pthq_16_2(2)-
273.16)*1.8+32.,ve_16_2/.3048,pthq_16_2(4)*3.4152);
fprintf(fid,'_16_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_16_2(2)-273.16)*1.8+32.,(pthq_16_3(2)-
273.16)*1.8+32.,ve_16_3/.3048,pthq_16_3(4)*3.4152);
fprintf(fid,'_16_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_16_3(2)-273.16)*1.8+32.,(pthq_16_4(2)-
273.16)*1.8+32.,ve_16_4/.3048,pthq_16_4(4)*3.4152);
fprintf(fid,'_16_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_16_4(2)-273.16)*1.8+32.,(pthq_16_5(2)-
273.16)*1.8+32.,ve_16_5/.3048,pthq_16_5(4)*3.4152);
fprintf(fid,'_16_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_16_6(2)-273.16)*1.8+32.,(pthq_16_6(2)-
273.16)*1.8+32.,ve_16_6/.3048,pthq_16_6(4)*3.4152);
 %floor _17
fprintf(fid,'_17_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_16_1(2)-273.16)*1.8+32.,(pthq_17_1(2)-
273.16)*1.8+32.,ve_17_1/.3048,pthq_17_1(4)*3.4152);
fprintf(fid,'_17_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_17_1(2)-273.16)*1.8+32.,(pthq_17_2(2)-
273.16)*1.8+32.,ve_17_2/.3048,pthq_17_2(4)*3.4152);
fprintf(fid,'_17_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_17_2(2)-273.16)*1.8+32.,(pthq_17_3(2)-
273.16)*1.8+32.,ve_17_3/.3048,pthq_17_3(4)*3.4152);
fprintf(fid,'_17_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_17_3(2)-273.16)*1.8+32.,(pthq_17_4(2)-
273.16)*1.8+32.,ve_17_4/.3048,pthq_17_4(4)*3.4152);
fprintf(fid,'_17_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_17_4(2)-273.16)*1.8+32.,(pthq_17_5(2)-
273.16)*1.8+32.,ve_17_5/.3048,pthq_17_5(4)*3.4152);
fprintf(fid,'_17_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_17_6(2)-273.16)*1.8+32.,(pthq_17_6(2)-
273.16)*1.8+32.,ve_17_6/.3048,pthq_17_6(4)*3.4152);
 %floor _18
fprintf(fid,'_18_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_17_1(2)-273.16)*1.8+32.,(pthq_18_1(2)-
273.16)*1.8+32.,ve_18_1/.3048,pthq_18_1(4)*3.4152);
fprintf(fid,'_18_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_18_1(2)-273.16)*1.8+32.,(pthq_18_2(2)-
273.16)*1.8+32.,ve_18_2/.3048,pthq_18_2(4)*3.4152);
fprintf(fid,'_18_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_18_2(2)-273.16)*1.8+32.,(pthq_18_3(2)-
273.16)*1.8+32.,ve_18_3/.3048,pthq_18_3(4)*3.4152);
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fprintf(fid,'_18_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_18_3(2)-273.16)*1.8+32.,(pthq_18_4(2)-
273.16)*1.8+32.,ve_18_4/.3048,pthq_18_4(4)*3.4152);
fprintf(fid,'_18_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_18_4(2)-273.16)*1.8+32.,(pthq_18_5(2)-
273.16)*1.8+32.,ve_18_5/.3048,pthq_18_5(4)*3.4152);
fprintf(fid,'_18_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_18_6(2)-273.16)*1.8+32.,(pthq_18_6(2)-
273.16)*1.8+32.,ve_18_6/.3048,pthq_18_6(4)*3.4152);
 %floor _19
fprintf(fid,'_19_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_18_1(2)-273.16)*1.8+32.,(pthq_19_1(2)-
273.16)*1.8+32.,ve_19_1/.3048,pthq_19_1(4)*3.4152);
fprintf(fid,'_19_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_19_1(2)-273.16)*1.8+32.,(pthq_19_2(2)-
273.16)*1.8+32.,ve_19_2/.3048,pthq_19_2(4)*3.4152);
fprintf(fid,'_19_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_19_2(2)-273.16)*1.8+32.,(pthq_19_3(2)-
273.16)*1.8+32.,ve_19_3/.3048,pthq_19_3(4)*3.4152);
fprintf(fid,'_19_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_19_3(2)-273.16)*1.8+32.,(pthq_19_4(2)-
273.16)*1.8+32.,ve_19_4/.3048,pthq_19_4(4)*3.4152);
fprintf(fid,'_19_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_19_4(2)-273.16)*1.8+32.,(pthq_19_5(2)-
273.16)*1.8+32.,ve_19_5/.3048,pthq_19_5(4)*3.4152);
fprintf(fid,'_19_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_19_6(2)-273.16)*1.8+32.,(pthq_19_6(2)-
273.16)*1.8+32.,ve_19_6/.3048,pthq_19_6(4)*3.4152);
 %floor _20
fprintf(fid,'_20_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_19_1(2)-273.16)*1.8+32.,(pthq_20_1(2)-
273.16)*1.8+32.,ve_20_1/.3048,pthq_20_1(4)*3.4152);
fprintf(fid,'_20_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_20_1(2)-273.16)*1.8+32.,(pthq_20_2(2)-
273.16)*1.8+32.,ve_20_2/.3048,pthq_20_2(4)*3.4152);
fprintf(fid,'_20_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_20_2(2)-273.16)*1.8+32.,(pthq_20_3(2)-
273.16)*1.8+32.,ve_20_3/.3048,pthq_20_3(4)*3.4152);
fprintf(fid,'_20_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_20_3(2)-273.16)*1.8+32.,(pthq_20_4(2)-
273.16)*1.8+32.,ve_20_4/.3048,pthq_20_4(4)*3.4152);
fprintf(fid,'_20_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_20_4(2)-273.16)*1.8+32.,(pthq_20_5(2)-
273.16)*1.8+32.,ve_20_5/.3048,pthq_20_5(4)*3.4152);
fprintf(fid,'_20_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_20_6(2)-273.16)*1.8+32.,(pthq_20_6(2)-
273.16)*1.8+32.,ve_20_6/.3048,pthq_20_6(4)*3.4152);
 %floor _21
fprintf(fid,'_21_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_20_1(2)-273.16)*1.8+32.,(pthq_21_1(2)-
273.16)*1.8+32.,ve_21_1/.3048,pthq_21_1(4)*3.4152);
fprintf(fid,'_21_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_21_1(2)-273.16)*1.8+32.,(pthq_21_2(2)-
273.16)*1.8+32.,ve_21_2/.3048,pthq_21_2(4)*3.4152);
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fprintf(fid,'_21_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_21_2(2)-273.16)*1.8+32.,(pthq_21_3(2)-
273.16)*1.8+32.,ve_21_3/.3048,pthq_21_3(4)*3.4152);
fprintf(fid,'_21_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_21_3(2)-273.16)*1.8+32.,(pthq_21_4(2)-
273.16)*1.8+32.,ve_21_4/.3048,pthq_21_4(4)*3.4152);
fprintf(fid,'_21_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_21_4(2)-273.16)*1.8+32.,(pthq_21_5(2)-
273.16)*1.8+32.,ve_21_5/.3048,pthq_21_5(4)*3.4152);
fprintf(fid,'_21_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_21_6(2)-273.16)*1.8+32.,(pthq_21_6(2)-
273.16)*1.8+32.,ve_21_6/.3048,pthq_21_6(4)*3.4152);
 %floor _22
fprintf(fid,'_22_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_21_1(2)-273.16)*1.8+32.,(pthq_22_1(2)-
273.16)*1.8+32.,ve_22_1/.3048,pthq_22_1(4)*3.4152);
fprintf(fid,'_22_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_22_1(2)-273.16)*1.8+32.,(pthq_22_2(2)-
273.16)*1.8+32.,ve_22_2/.3048,pthq_22_2(4)*3.4152);
fprintf(fid,'_22_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_22_2(2)-273.16)*1.8+32.,(pthq_22_3(2)-
273.16)*1.8+32.,ve_22_3/.3048,pthq_22_3(4)*3.4152);
fprintf(fid,'_22_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_22_3(2)-273.16)*1.8+32.,(pthq_22_4(2)-
273.16)*1.8+32.,ve_22_4/.3048,pthq_22_4(4)*3.4152);
fprintf(fid,'_22_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_22_4(2)-273.16)*1.8+32.,(pthq_22_5(2)-
273.16)*1.8+32.,ve_22_5/.3048,pthq_22_5(4)*3.4152);
fprintf(fid,'_22_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_22_6(2)-273.16)*1.8+32.,(pthq_22_6(2)-
273.16)*1.8+32.,ve_22_6/.3048,pthq_22_6(4)*3.4152);
 %floor _23
fprintf(fid,'_23_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_22_1(2)-273.16)*1.8+32.,(pthq_23_1(2)-
273.16)*1.8+32.,ve_23_1/.3048,pthq_23_1(4)*3.4152);
fprintf(fid,'_23_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_23_1(2)-273.16)*1.8+32.,(pthq_23_2(2)-
273.16)*1.8+32.,ve_23_2/.3048,pthq_23_2(4)*3.4152);
fprintf(fid,'_23_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_23_2(2)-273.16)*1.8+32.,(pthq_23_3(2)-
273.16)*1.8+32.,ve_23_3/.3048,pthq_23_3(4)*3.4152);
fprintf(fid,'_23_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_23_3(2)-273.16)*1.8+32.,(pthq_23_4(2)-
273.16)*1.8+32.,ve_23_4/.3048,pthq_23_4(4)*3.4152);
fprintf(fid,'_23_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_23_4(2)-273.16)*1.8+32.,(pthq_23_5(2)-
273.16)*1.8+32.,ve_23_5/.3048,pthq_23_5(4)*3.4152);
fprintf(fid,'_23_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_23_6(2)-273.16)*1.8+32.,(pthq_23_6(2)-
273.16)*1.8+32.,ve_23_6/.3048,pthq_23_6(4)*3.4152);
 %floor _24
fprintf(fid,'_24_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_23_1(2)-273.16)*1.8+32.,(pthq_24_1(2)-
273.16)*1.8+32.,ve_24_1/.3048,pthq_24_1(4)*3.4152);
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fprintf(fid,'_24_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_24_1(2)-273.16)*1.8+32.,(pthq_24_2(2)-
273.16)*1.8+32.,ve_24_2/.3048,pthq_24_2(4)*3.4152);
fprintf(fid,'_24_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_24_2(2)-273.16)*1.8+32.,(pthq_24_3(2)-
273.16)*1.8+32.,ve_24_3/.3048,pthq_24_3(4)*3.4152);
fprintf(fid,'_24_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_24_3(2)-273.16)*1.8+32.,(pthq_24_4(2)-
273.16)*1.8+32.,ve_24_4/.3048,pthq_24_4(4)*3.4152);
fprintf(fid,'_24_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_24_4(2)-273.16)*1.8+32.,(pthq_24_5(2)-
273.16)*1.8+32.,ve_24_5/.3048,pthq_24_5(4)*3.4152);
fprintf(fid,'_24_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_24_6(2)-273.16)*1.8+32.,(pthq_24_6(2)-
273.16)*1.8+32.,ve_24_6/.3048,pthq_24_6(4)*3.4152);
 %floor _25
fprintf(fid,'_25_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_24_1(2)-273.16)*1.8+32.,(pthq_25_1(2)-
273.16)*1.8+32.,ve_25_1/.3048,pthq_25_1(4)*3.4152);
fprintf(fid,'_25_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_25_1(2)-273.16)*1.8+32.,(pthq_25_2(2)-
273.16)*1.8+32.,ve_25_2/.3048,pthq_25_2(4)*3.4152);
fprintf(fid,'_25_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_25_2(2)-273.16)*1.8+32.,(pthq_25_3(2)-
273.16)*1.8+32.,ve_25_3/.3048,pthq_25_3(4)*3.4152);
fprintf(fid,'_25_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_25_3(2)-273.16)*1.8+32.,(pthq_25_4(2)-
273.16)*1.8+32.,ve_25_4/.3048,pthq_25_4(4)*3.4152);
fprintf(fid,'_25_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_25_4(2)-273.16)*1.8+32.,(pthq_25_5(2)-
273.16)*1.8+32.,ve_25_5/.3048,pthq_25_5(4)*3.4152);
fprintf(fid,'_25_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_25_6(2)-273.16)*1.8+32.,(pthq_25_6(2)-
273.16)*1.8+32.,ve_25_6/.3048,pthq_25_6(4)*3.4152);
 %floor _26
fprintf(fid,'_26_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_25_1(2)-273.16)*1.8+32.,(pthq_26_1(2)-
273.16)*1.8+32.,ve_26_1/.3048,pthq_26_1(4)*3.4152);
fprintf(fid,'_26_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_26_1(2)-273.16)*1.8+32.,(pthq_26_2(2)-
273.16)*1.8+32.,ve_26_2/.3048,pthq_26_2(4)*3.4152);
fprintf(fid,'_26_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_26_2(2)-273.16)*1.8+32.,(pthq_26_3(2)-
273.16)*1.8+32.,ve_26_3/.3048,pthq_26_3(4)*3.4152);
fprintf(fid,'_26_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_26_3(2)-273.16)*1.8+32.,(pthq_26_4(2)-
273.16)*1.8+32.,ve_26_4/.3048,pthq_26_4(4)*3.4152);
fprintf(fid,'_26_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_26_4(2)-273.16)*1.8+32.,(pthq_26_5(2)-
273.16)*1.8+32.,ve_26_5/.3048,pthq_26_5(4)*3.4152);
fprintf(fid,'_26_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_26_6(2)-273.16)*1.8+32.,(pthq_26_6(2)-
273.16)*1.8+32.,ve_26_6/.3048,pthq_26_6(4)*3.4152);
 %floor _27
```

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fprintf(fid,'_27_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_26_1(2)-273.16)*1.8+32.,(pthq_27_1(2)-
273.16)*1.8+32.,ve_27_1/.3048,pthq_27_1(4)*3.4152);
fprintf(fid,'_27_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_27_1(2)-273.16)*1.8+32.,(pthq_27_2(2)-
273.16)*1.8+32.,ve_27_2/.3048,pthq_27_2(4)*3.4152);
fprintf(fid,'_27_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_27_2(2)-273.16)*1.8+32.,(pthq_27_3(2)-
273.16)*1.8+32.,ve_27_3/.3048,pthq_27_3(4)*3.4152);
fprintf(fid,'_27_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_27_3(2)-273.16)*1.8+32.,(pthq_27_4(2)-
273.16)*1.8+32.,ve_27_4/.3048,pthq_27_4(4)*3.4152);
fprintf(fid,'_27_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_27_4(2)-273.16)*1.8+32.,(pthq_27_5(2)-
273.16)*1.8+32.,ve_27_5/.3048,pthq_27_5(4)*3.4152);
fprintf(fid,'_27_6: %7.2f, %7.2f, %7.3f, %7.3f\n',(pthqu_27_6(2)-273.16)*1.8+32.,(pthq_27_6(2)-
273.16)*1.8+32.,ve_27_6/.3048,pthq_27_6(4)*3.4152);
 %floor _28
fprintf(fid,'_28_1: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_27_1(2)-273.16)*1.8+32.,(pthq_28_1(2)-
273.16)*1.8+32.,ve_28_1/.3048,pthq_28_1(4)*3.4152);
fprintf(fid,'_28_2: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_28_1(2)-273.16)*1.8+32.,(pthq_28_2(2)-
273.16)*1.8+32.,ve_28_2/.3048,pthq_28_2(4)*3.4152);
fprintf(fid,'_28_3: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_28_2(2)-273.16)*1.8+32.,(pthq_28_3(2)-
273.16)*1.8+32.,ve_28_3/.3048,pthq_28_3(4)*3.4152);
fprintf(fid,'_28_4: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_28_3(2)-273.16)*1.8+32.,(pthq_28_4(2)-
273.16)*1.8+32.,ve_28_4/.3048,pthq_28_4(4)*3.4152);
fprintf(fid,'_28_5: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_28_4(2)-273.16)*1.8+32.,(pthq_28_5(2)-
273.16)*1.8+32.,ve_28_5/.3048,pthq_28_5(4)*3.4152);
fprintf(fid,'_28_6: %7.2f, %7.2f, %7.3f, %7.3f\n', (pthq_28_5(2)-273.16)*1.8+32.,(pthq_28_6(2)-
273.16)*1.8+32.,ve_28_6/.3048,pthq_28_6(4)*3.4152);

fclose(fid);
```